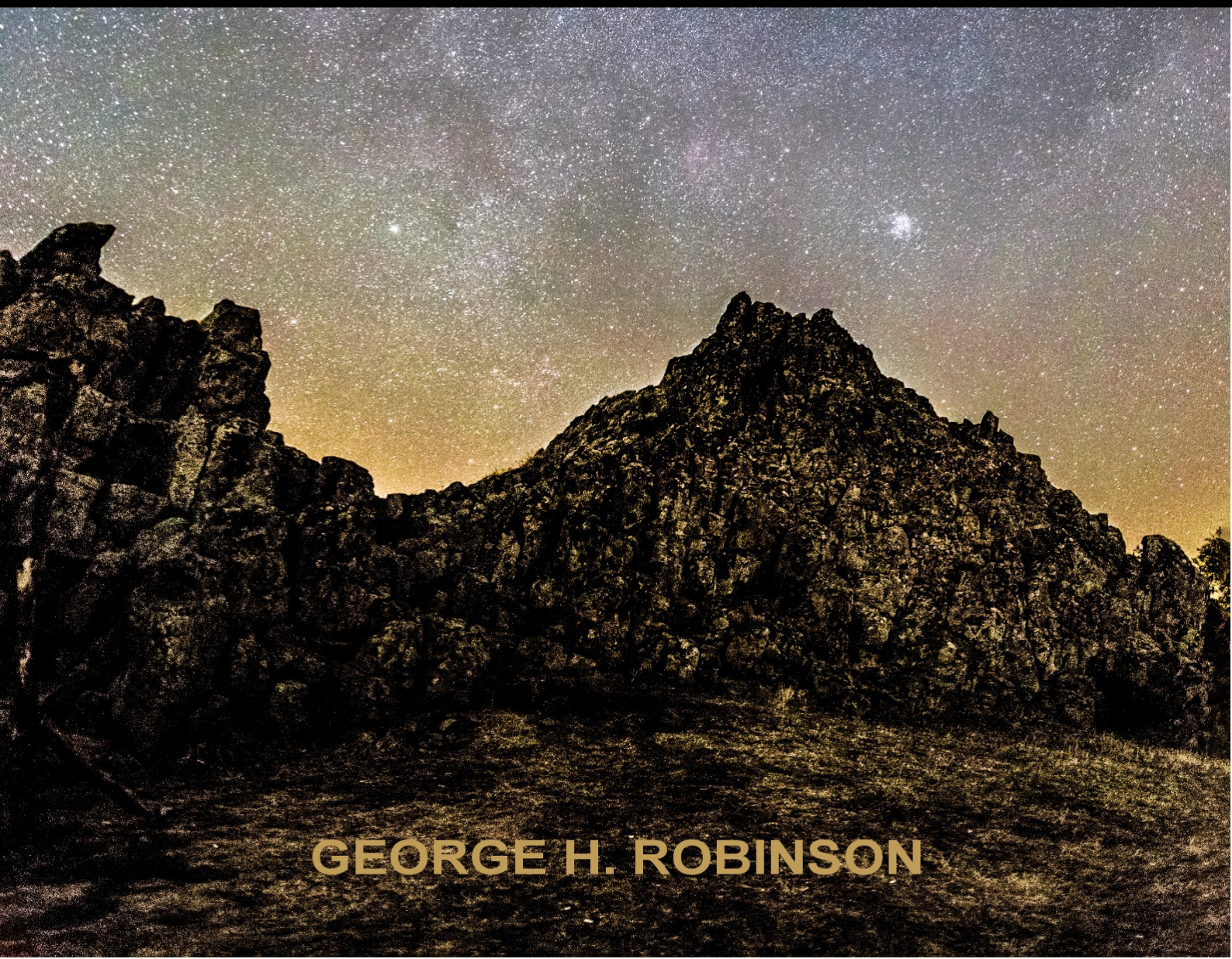


**LIMITS ON HOW WE VIEW AND
INTERPRET THE UNIVERSE**



PERCEPTUAL BOUNDARIES



GEORGE H. ROBINSON

Perceptual Boundaries

Limits on How We View and Interpret the Universe

by George H. Robinson

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*The evidence suggests that we are, despite the illusory appearance of things,
barely aware of our environment.*

— George H. Robinson

Preface

For many decades I have, possibly as a result of brief encounters with philosophy and its related questions, wondered about reality and what is known with any degree of certitude. This kind of concern involves the philosophical discipline of epistemology (or theory of knowledge, including what we know and how we acquire that knowledge). Many of its concerns are tangential to questions arising in various scientific disciplines in which attempts are made to investigate, evaluate, and (possibly) resolve them. Questions that not only I but also others have raised involve the nature of reality, how we can know it, what are our origins (not immediate ancestry but, rather, the origin of humans and other species), and the origin of the Solar System and Universe.

This started, as I recall, decades ago with my first inexpensive refractor telescope having an objective diameter of 60 mm. This limited my view of the Universe, consisting for me of the Moon, planets of the Solar System, and nearby stars of the Milky Way galaxy. Although my environment was, compared to the present, fairly free of light pollution, I was unaware of galaxies beyond the Milky Way. Even with this limited view of the Universe (comparable to that of those living before Galileo), I was mystified by its immensity as I perceived it through my small telescope (which did permit me to see the four Galilean moons of Jupiter). As with others (similarly observing with more powerful telescopes), I experienced a certain amount of awe that made me wonder where did these stars and planets come from, and what can we know about the extent and origin of all that we see.

Quite apart from my amateur astronomical observations were questions about the origin of life. Even everyday happenings raise questions of "why" that have been answered in various ways over the centuries. Thunder occurs as a result of the Nordic thunder god Thor (whose existence may, for most people today, be remembered indirectly as Thor's day, or more familiarly, Thursday). One way of accounting for the mysteries humans encounter has been to appeal to religious mythology. Until recently, these questions have been mostly speculated about in the absence of cumulative scientific knowledge that permits attending to more plausible answers based on empirical and (in some cases) replicable findings and less attention to answers arising from non-empirical sources. The intellectual fields of science, philosophy, and religion have, over the years, provided in many instances, separate answers to these (and related) questions. In some cases the answers are in agreement, while in others they are very different. Individual preference for one type of

answer may depend upon the scientific, philosophical, or religious orientation one has when approaching these topics. While recognizing these varied approaches to knowledge, my concern is to approach the questions relating to our awareness of the environment around us utilizing scientific (i.e., empirical) methods and findings.

This is no guarantee of knowledge certainty, but it does provide a greater amount of agreement about what is known (or unknown). This is not to deny other methods. It, simply, increases the probability of agreement across observers as to what is veridical (i.e., real, in the sense of naïve realism) or how we can establish (or determine) what is veridical. My concerns about the veridicality of my perceptions result from an increasing awareness of the limitations imposed by our senses, memories, and cognitive biases that we possess, knowingly or unknowingly.

The phrase "Seeing is believing" may accurately describe the basis of belief. Our increasing awareness of illusions, hallucinations, eyewitness testimony differences, and political disputes suggest inadequacies of this aphorism. Modern electronic technology, with its objective recording of events, is increasingly replacing human observation and memory because of the absence of agreement among different human observers. The fallibility of human observation and memory necessitating these changes is the subject of this book. Perception is indeed a complex subject and not comprehensively covered in this book. However, I hope to leave the reader with an appreciation of the fact that our perceptions come bundled with limitations, and these limitations have consequences.

Some notes on notation: In order to improve and, hopefully, maintain clarity throughout the book, I will use the following slightly unusual conventions. Statistical probability (or p) values are given with a zero preceding the decimal point, e.g., $p < 0.05$, in contrast to its customary omission in statistical results. There is no change in meaning. It is done simply for clarification of results for those unfamiliar with statistical conventions. Another numerical change used is the symbol $\wedge$ for exponentiation. For example, 3 squared may be written as 3^2 , which equals 9. Negative exponents will be given by the numerical magnitude enclosed within parentheses in order to reduce possible confusion. As an example, $2^{(-4)} = 0.0625$. The reason for this is that the fact of exponentiation may be lost when initially printed (or reprinted). I remember encountering a reported algorithmic error rate of one in 1014, which I considered to be rather high. Later I guessed that the actual error rate (intended) was probably one in 10^{14} , a much more satisfying value (if true). The problem seems to occur

when moving across word processors, which represent exponentiation differently. Since the symbol $\wedge$ exists as an ASCII symbol (Decimal 94) and is also present on standard keyboards, this eliminates the need to search for a special way for symbolizing exponentiation.

Continuing notes on notation: A rather different problem arises with the use of the word "billion." This word has been favored by politicians such as Everett Dirksen who was credited (perhaps inaccurately) with the statement: "A billion here, a billion there, pretty soon it adds up to real money." Had he said this before the British House of Commons to listeners who interpreted his wording to mean the British long scale billion, it would add up to much more money than it probably did to an American audience. The British long scale billion is 10^{12} (or one million million), while the short scale billion is 10^9 (or one thousand million). Customary usage has tended to replace, in modern terminology (particularly in the United States), the word billion with its short scale meaning. Astronomers use the word billion frequently and, as far as I know, mean by it 10^9 (i.e., a short scale billion). This ambiguity continues for larger numbers as well, such as a trillion, etc. To reduce any possible ambiguity, I have adopted the (admittedly cumbersome) phrase thousand million as a replacement (except in quotations from others) for the word "billion." There remain phrases appearing in the popular press whose meanings evade me, such as reports of a galaxy containing a billion and a half stars. I can guess that the billion refers to a short scale (10^9) billion but have no idea what the half star is. The nature of this interpretive difficulty becomes clearer if one successively replaces the word "billion" with "million," "thousand," "hundred," or "ten." As the reader will see, there are many mysteries (to be described in later chapters) that exist in the Universe. Linguistic precision and accuracy should assist in clarifying the nature of these mysteries.

I wish to thank my wife, Nancy B. Robinson, who has served throughout this project as both copy and general editor and, also, a translational agent in converting my word-processed text into eBook format. Her knowledge of HTML coding and validation requirements has made the transition possible.

George H. Robinson
May 2018

Chapter 1 – Visual and Auditory Perceptions

Veridical Perceptions

When I see before me what others may describe as a brick wall, and I attempt to penetrate it (quite unsuccessfully) and, upon future occurrences of similar sightings with equally unsuccessful penetration attempts, I develop a percept of a non-penetrable wall. This is an example of veridical perception.

Similarly, other correlated experiences (visually, tactilely, and through other senses) in my phenomenal environment cause me to develop other veridical percepts in which I formulate an idea of reality (naïve realism) that indicates that what I experience through the senses is an accurate representation of that reality. Why this should be possible has been the subject of much philosophical and scientific debate over the years. Some have maintained that the mind or brain is hard-wired to perceive our environment accurately. This view is the nativist position and maintains that we are born with, effectively, some knowledge to which is added information we receive through the senses. An illustration (not usually given) is the human eye, whose sensitivity in daylight (the photopic luminosity response) corresponds at its peak wavelength with the peak luminosity of light from the sun at ground level (at 555 nm). Another example involving the vision of frogs will be given later. Some aspects of human language are believed to be innate, while the particular language learned and used is regarded as mainly learned (Psychological nativism, 2016).

An alternative view of our perceptual acquisition of knowledge of the world around us is given by the philosophical position called empiricism. The fundamental idea is that all of our knowledge comes to us through the senses; the mind at birth is a blank slate (*tabula rasa*) to which is added information gained through the senses as we experience the world around us. A well known example of this view is given by the philosopher John Locke (1690) in his *An Essay Concerning Human Understanding*. In this essay, he quotes from a letter he received from a Mr. Molineux [Molyneux] that stated the following:

Suppose a man born blind, and now adult, and taught by touch to distinguish between a cube and a sphere of the same metal, and nighly of the same bigness, so as to tell, when he felt one and the other, which is the cube, which the sphere. Suppose then the cube and sphere placed on a table, and the blind man be made to see: *quaere*, whether by his sight,

before he touched them, he could now distinguish and tell which is the globe, which the cube? ...

Locke continues:

I agree ... and am of opinion that the blind man, at first sight, would not be able to say with certainty which was the globe, which the cube, whilst he only saw them; though he could unerringly name them by his touch, and certainly distinguish them by the difference of their figures felt.

In his empirical view, Locke considered the idea of a cube and of a sphere to be unavailable to the mind visually until the person had actually sighted and had experience with them. At the time he wrote this, it remained a philosophical idea presented as a thought experiment. Since then, however, evidence has become available providing an answer to this question quoted by Locke.

Locke revisited:

Although unanswered empirically by Locke (1690), a surgical procedure, which has been utilized to provide vision to individuals without vision since birth, has been used to provide just such an answer. This source of evidence involves the consequences of an operation to provide vision to those whose vision has been impaired as a result of a cloudiness of the lens. This cloudiness is called a cataract and adversely affects many elderly people and, also, their pets (e.g., dogs). The cloudiness appears, in many cases, as a milky white near-opacity in the lens surrounded by the pupil of the eye. (Note: There are many variations of cataract appearance.) The cloudy cataract permits light-dark discrimination (and global color discrimination) but prevents form vision to an extent determined by the degree of opacity (reduced translucency). Although this problem usually occurs late in life after many years of normal vision, it affects some individuals from birth in the form of unilateral or bilateral congenital cataracts, thus preventing the subsequent years of normal vision in bilateral cases unless the cataractous lens(es) is (are) surgically removed at an early age. In some cases restoration of vision has been provided as a consequence of corneal grafts for patients experiencing loss of form vision at an early age because of bilateral damage to the corneas.

Most instances of visual recovery have resulted from the removal of bilateral congenital cataracts, as summarized by the retrospective study of von Senden (1932/1960), with varying descriptions of initial post-operative visual quality. One case of vision restoration, not by removal of bilateral congenital cataracts

but instead by binocular corneal grafting, is that of a patient known as S.B., described and investigated in considerable detail by Gregory and Wallace (1963). They provide considerable information about the history, education, general activity, and sensory (tactile, etc.) capabilities of S.B., pre- and post-operative. In addition, correspondence from the surgeon, Mr. A. Hirtenstein, and from Dr. von Senden is included, providing additional information about the immediate pre-operative and post-operative behavior of S.B. and answers from von Senden relating to the vision of his sample of cases.

For those with visual recovery (whether from cataract surgery or from a cornea graft), the pre-operative vision consisted, variously, from light sensitivity to some color discrimination to very limited pattern vision. It was not a complete absence of visual stimulation, which can lead to irreversible complete light insensitivity (complete blindness), thus rendering either corrective operation ineffective for any visual restoration. If there is complete insensitivity (blindness), as indicated by artificially stimulating the dark-adapted retina through a trans-scleral directed light with no report of visualization of the retinal vascularization by the patient, the operation would not be done. When done, the pre- to post-operative changes went from very limited (or no) visual behavior to less limited visual behavior, requiring a large amount of discrimination learning depending upon the degree of prior visual deprivation (among other factors, including motivation). Gregory and Wallace quote von Senden (1960) as indicating: "Thus von Senden thinks that only four out of nearly seventy cases can be said to have had only brightness vision before the operation (and at least one of these [Latta, 1904] developed useful vision comparable with the case of S.B.)."

It is the case, however, that visual competence developed slowly through learning. Illustrating this, S.B. is quoted saying: "I'd pick up a fork, feel it and remembering how a fork felt when I was blind I could say: 'This is a fork.' Then I had to learn to remember it the next time I saw it" (Correspondence from von Senden to A. Hirtenstein, quoted by Gregory and Wallace, 1963). It would appear that this observation, along with many others involving S.B. and other patients having restored sight following cataract or corneal grafting operations, is consistent with the empirical view of John Locke (1690). Despite the incompleteness of the data of von Senden (1932), Donald Hebb (1949) in his influential book, *The Organization of Behavior*, considered the implications of restored sight to be significant in the influence of learning on visual perception, although he (later) tempered his view somewhat (Hebb, 1966, pp. 148–149). Riesen's (1947) study of the influence of darkness-rearing of chimpanzees with similar deficits when exposed to light also, because of the possibility of retinal degeneration, served to modify Hebb's

(1966) view of the strength of the influence of limited deprivation on subsequent visual perception.

Highly related to Locke's (1690) concern is the question of innateness of perception. Much (but not all), according to the findings of restored vision, of visual perception requires learning by association between visual inputs and those inputs from other senses, particularly tactile. In order to experimentally investigate this with neurologically intact subjects, Walk and Gibson (1961) have described apparatuses and results from three versions of what they call a "visual cliff." This apparatus (types two and three were modified versions) consisted of a board placed over thick, weight-bearing clear glass, permitting a view on either side of the board of a textured pattern. This pattern was either immediately below the glass (shallow side) or 40 inches [type 3] below the glass (deep side). An animal (tested subjects included, "... , rats, ... , chickens, turtles, lambs, kids, pigs, dogs, cats, monkeys, and human infants") would be placed on the board separating the shallow and deep sides and observed to see how long it took before and in which direction the subject moved off the board onto either the shallow or deep side. Clear preference for the shallow side indicated depth perception.

Walk and Gibson (1961) found a clear difference on day 1 of testing for cats raised in darkness vs. those raised in light. Dark reared cats had normal pupil responses but did not avoid the deep side of the visual cliff, while those raised in light did avoid the deep side. Cats raised in darkness initially bumped into walls and had some difficulty getting around. Over a period of 7 days in light, dark raised cats improved in avoiding the deep side monotonically from about 50%, initially, to 100%. Recovery of dark-reared kittens seemed to be complete by 10 days in the light. Dark-reared hooded rats were not deficient on the visual cliff when first tested. Chicks, lambs, and kids [goats] showed depth perception on day 1 after birth. Some animals exhibit an apparent innate ability for depth perception (chicks, lambs, kids [goats]), whereas kittens, monkeys, and human infants seem to require a period of light experience in order to develop depth perception, as indicated by preferences for moving into the shallow side of the visual cliff after such exposure. Walk and Gibson conclude that "... innate mechanisms for discriminating depth may be supplemented by the acquisition of a learned cue."

Consider a less complicated illustration of the visual system described by Lettvin, Maturana, McCulloch, and Pitts (1959) in their classic article, "What the Frog's Eye Tells the Frog's Brain." By electrically monitoring sampled sites within the optic nerve and the superior colliculus (optic tectum) of frogs that were provided with various visual stimuli, they found specific reactions

to four types of stimuli. Some neurons in the optic nerve responded to “1) local sharp edges and contrast, 2) the curvature or edge of a dark object, 3) the movement of edges, and 4) the local dimmings produced by movement or rapid general darkening” (Lettvin, et al., 1959). Although the functional arrangement among the fibers of the optic nerve seemed to be scrambled, there was a clear mapping of the visual field of the contralateral eye along the optic tectum and, also, a separation by function (from surface to deepest) with contrast, convexity, moving edges, and dimming detection arranged in layers, respectively. Sperry (1951), as part of his summarizing of his earlier work with frogs (and other amphibia), describes the functional reconnection of sectioned optic nerves through regeneration to appropriate parts of the optic lobe (tectum), possibly by chemoaffinity. The apparent preprocessing by the eye seems to provide survival value in avoiding predators and obtaining food. The frog, however, seems to be blind to non-moving food (e.g., a dead or motionless fly) placed before it.

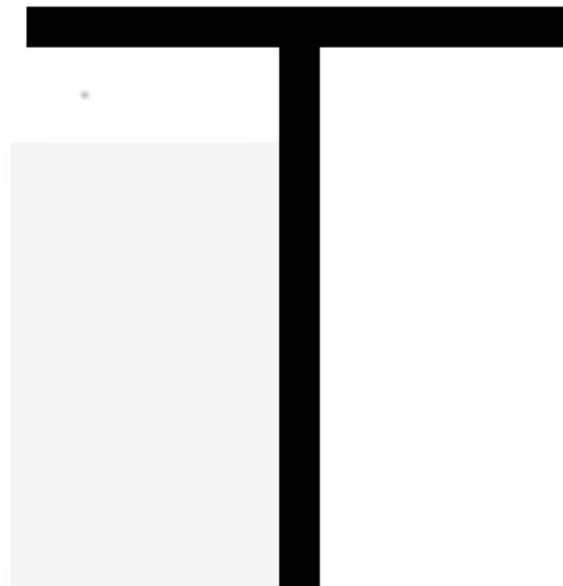
Although frogs may be unable to learn to adapt to a rearrangement of their visual world as a consequence of the surgical rotation of the eye in its orbit (Sperry, 1951), humans seem to have limited success. Stratton (1896, 1897) constructed a unit-power monocular telescope with two convex lenses of equal focal length, which had the optical effect of rotating the visual field 180 degrees (i.e., inverting the image on the retina to an upright position and reversing the left-right dimension). It had been known since the theoretical work of Johannes Kepler and the experimental confirmation by Christopher Scheiner in the first half of the 17th century that the retinal image of the seen world was inverted (Polyak, 1957, pp. 36–38). What was unknown was why do we not see everything upside down. While wearing his visual-field-inverting device, Stratton kept a diary of his visual experiences over a period of 8 days (in his second experimental session). Naturally, this inversion on the retina had an effect of making coordinated movements between his eye and hands difficult. There was some adaptation to the rearrangement of visual space after 8 days, but the amount of possible adaptation is better indicated by the later experimental investigation by Snyder and Pronko (1952) in which they used a binocular unit-power set of telescopes worn by a graduate student for all minutes of the waking day for 30 days. Instead of simply recording a diary account of their responses, they utilized a collection of standard laboratory perceptual-motor skill tests, the results of which were recorded and graphically displayed. As experienced by Stratton, there were difficulties with the narrow (20-degree) field of view provided by the optical system. Over the 30-day period, there was clear improvement in each of the tasks (mirror tracing, Purdue Pegboard, card sorting, etc.) to the point of exceeding test trial performance prior to inverting lens use. From this work it appears that

perception of the visual world includes a very large learned component that includes tactile-visual associations.

Illusory Perceptions

Perceiving the world requires sensitivity provided by the various senses. When sensory input is interpreted in awareness accurately, the perception is said to be veridical or truthful (i.e., coinciding with reality without distortion). We are generally aware that non-veridical perceptions occur in the form of illusions. Many of these are visual, although some occur with other senses and are more difficult to describe in a book. Wikipedia has, for example, instances of auditory illusions (requiring MP3 players to demonstrate). Magicians employ illusions as a basis of their performances.

Optical (or visual) illusions illustrate nicely the difference between veridical and non-veridical perceptions. The horizontal-vertical (H-V) illusion is an example of this difference, as shown in **Figure 1.1**. The illusory magnitude can be observed and psychophysically measured, thus revealing (in this case) the quantitative difference between veridical and apparent reality. People generally (but not always) regard the vertical component to be longer than the horizontal component in this inverted version of the horizontal-vertical illusion.



[Figure 1.1] *The Horizontal-Vertical Illusion*

The horizontal-vertical illusion may be quantitatively evaluated by drawing a horizontal line and a much longer vertical line, beginning at the middle of (bisecting) the horizontal line and extending downward. A subject is then

asked to move an opaque covering card over the vertical line so as to make the uncovered portion of the vertical line subjectively equal in length to the horizontal line. In order to get a stable estimate of the magnitude of the illusory error, several trials, both ascending (increasing the length of the exposed vertical line) and descending (decreasing its length), should be conducted and averaged.

Although the horizontal-vertical illusion may seem to be a laboratory curiosity, naturally occurring phenomena present their own illusory perceptions (which is not to say that the H-V illusion doesn't occur in natural settings). A commonly experienced illusion is the moon illusion. The apparent size of the moon on the horizon is generally seen as much larger than its appearance when directly above (at, or near, zenith). This illusion has been known and theorized about for the past 2500 years (Plug and Ross, 1989). Numerous ideas have been suggested in attempts to explain why the moon and sun appear larger on the horizon and appear smaller (despite each subtending an angle of 0.5 degrees in either position) as they ascend in the sky but with no completely satisfactory agreement. The illusion is limited to apparent size and not color changes, which are non-illusory and explained by Rayleigh scattering. A successive multiple exposure color photograph of the moon rising will reveal the color change and the constant size. Since the moon is slightly closer to the observer at zenith, it is actually slightly (but not noticeably) larger than at the horizon.

Delusional Perceptions

A delusional perception is a perception held by a person for which there is intersubjective agreement by others that the perception is false in one or more details. If the delusional perception is strongly held, it may indicate to some that the deluded person has some kind of mental defect. There are many cases of delusional perceptions. For example, some politicians or aspiring lovers may have motivated deluded beliefs about their attractiveness to others that are not (either fully or partly) intersubjectively shared. As such, the delusion(s) may be innocuous and diminish or disappear over time.

Delusional perceptions occur in some types of neuropsychiatric and neuropsychological disorders, such as schizophrenia, bipolar disorder, Alzheimer's disease, Lewy body dementia, and within some syndromes. The Capgras syndrome is a delusional perception characterized by an individual perceiving, for example, that his or her spouse (or some other significant person) is an impostor while recognizing that there is an identical physical

resemblance to the person being replaced by the impostor. In this example, other members of the family are correctly identified; the misidentification only applies to the spouse (or the significant other person).

Why the Capgras delusion occurs is not known. It may be related to a neurological disorder called prosopagnosia (face blindness) in which the affected individual is unable to recognize people by viewing their faces. They see the parts of the face but are unable to identify whose face it is unless there is some uniquely distinguishing feature. Once the person speaks, he or she is immediately recognizable by voice. Visually, however, the inability to recognize may be extreme. I have encountered several instances in the literature, illustrated by the quoted example provided by Farrah (1990, p.71): “At the club I saw someone strange staring at me, and asked the steward who it was. You’ll laugh at me. I’d been looking at myself in a mirror.” The person with Capgras syndrome seems to be clearly delusional, whereas the person with a severe case of prosopagnosia is clearly aware that he or she is having difficulty identifying a person until that person speaks (or is seen to have some visually outstanding distinguishing feature). Prosopagnosia is not a form of delusion; it may (or may not) be neurologically related to the Capgras syndrome, which goes unmentioned by Farah in her excellent coverage of visual agnosias.

Hallucinatory Perceptions

In contrast to delusions, which are ultimately (at least partially) based on some physically present stimulus that is misinterpreted in its significance, hallucinations are perceptions that occur without an obvious physical stimulus. As such, they vary in significance from vivid dreams while asleep to clear and usually visual or auditory perceptions of persons or things that are not present (as indicated by intersubjective agreement by others present). The hallucinatory significance for the person experiencing them is likely to depend upon their frequency of occurrence in the human population. For example, dreams seem to be universally experienced and have little significance when compared to the auditory hallucinations of someone diagnosed as schizophrenic or the visual hallucinations of a person with Lewy body dementia. Intermediate in significance are the hallucinations of a person having a hallucinogenic drug reaction or of an alcoholic suddenly withdrawing from all alcohol (delirium tremens) with associated auditory and/or visual hallucinations, among other symptoms. Hallucinations vary in their complexity, in dreams and in waking states, from light flashes or sounds of brief tones (in the absence of strong prior acoustic stimulation that may

generate a “ringing in the ears”) to complex well-formed elaborate visual (seeing people) or auditory (hearing music or voices) manifestations. Complex auditory hallucinations (e.g., voices) may appear to be originating within the head or outside the body.

Additionally, sensations may arise from an amputated limb (phantom limb syndrome) or from an eye that has been removed (phantom eye syndrome). In the latter case, there is not only pain apparently coming from the removed eye (as is generally the case in the phantom limb) but visual sensations may also occur. As described by Duke-Elder (1949): “The enucleation of an eye may be followed by persistent hallucinations, sometimes very dramatic and distressing, usually unformed, but sometimes formed. ... Abell (1845-46) gave a classical and dramatic account of the appearances seen by him on gradually going blind over a period of 4 years. Blindness in one eye was associated with smoke-like visions during the day and beautifully coloured patterns on the walls at night. Total blindness brought dramatic visions of vivid landscapes, parades of gorgeously caparisoned soldiers, cities, and multitudes of persons and animals, and many other wonderful and strange sights” (p. 3697).

Summary

We have looked into (appropriate phrasing, since most investigations have been concerned with vision) questions of veridicality in perception as applied to the idea of naïve realism, nativism vs. empiricism, findings of restored sight in adults blind since birth (or shortly thereafter), depth perception across species (as indicated by the visual cliff experiments), and the intransigence of vision in the frog. Considering varying amounts of complexity in responding, some primitive responses, e.g., heart beats and breathing, are necessary for basic survival in which response failure would lead to reproductive failure. Other responses, such as the imprinting of following, lead to greater survival and reproduction.

The work of Stratton and that of Snyder and Pronko using image inverting lenses to study perceptual-motor adaptation to modified visual inputs reveal considerable learning in humans. In addition to the perceptual malleability indicated, illusions, delusions, and hallucinations contribute sensory inputs which may make veridical perception of reality difficult. Assuming that one can rely upon an interpretation of reality provided under naïve realism, Chapter 2 illustrates how this information seems to be cognitively organized.

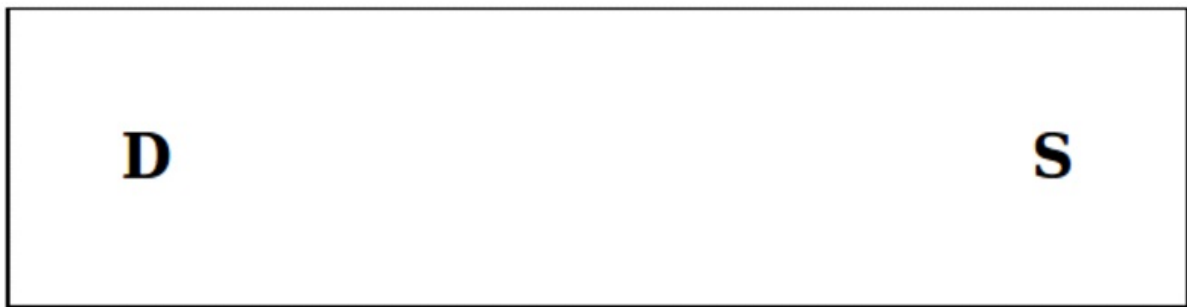
Chapter 2 – Sensory Inputs and Channels

Sensitivity to Environmental Stimuli

We perceive the world around us—or, at least, part of that world. Our presence within the sea of stimuli to which we are sensitive includes encounters with a multitude of potential stimuli to which we are not sensitive but other animals may be sensitive. These potential stimuli that we humans do not detect include infrasonic acoustic energy (frequencies below 15 Hz), ultrasonic energy (acoustic frequencies above 20,000 Hz), infrared wavelengths of light (longer than 750 nm), ultraviolet wavelengths (less than 400 nm), chemical stimuli which have no detectable taste (or do so for some people and not others), and, similarly, for gaseous chemicals to which some (or all) people are odor insensitive. Added to these are particles (radioactive or otherwise) that pass through our bodies without detection. More elusive for our perception are exotic particles, such as neutrinos, which have very little mass, no electric charge, and pass through our bodies at rates of perhaps trillions per second (and through the earth, as well) with our being completely unaware of the bombardment. Our vision has limitations in spatial and temporal resolution. The pattern  can be seen as a collection of dots or as a grey smudge depending upon the distance between the eye and stimulus. A flickering light that turns on and off at a rate of less than 30 times per second will, if increased in frequency, appear to be continuously on (as it exceeds the critical flicker frequency). This limitation has been applied in the form of motion pictures, providing the illusion of visual continuity through the rapid succession of discrete flicker-free pictures (above the critical flicker frequency through the mechanism of multiple shutter openings and closings per projected picture).

A relatively unknown (prior to the 18th century) visual limitation is known by the generic name color blindness (occasionally referred to as Daltonism after the famous chemist John Dalton who was afflicted with, and studied, this visual limitation). It occurs in several varieties, most of which do not involve complete color blindness. Afflicted individuals are likely to be unaware of their abnormality until specifically tested for it, since they see things normally, for them, throughout their life. Another limitation possessed by humans and other vertebrates with an inverted retina is the scotoma or blind spot in the visual field for each eye as a consequence of the retinal region in the back of the eye called the optic disc (or disk). Since this area has no photoreceptors, that part of the visual field imaged onto it cannot be seen. The

optic disc contains axons of ganglion cells and the central retinal artery and vein (Polyak, 1957, p. 260) but no rods or cones. It seems curious that the blind spot was apparently not discovered until the work of Edmé Mariotte in 1668 (Boring, 1942/1970, p. 121; Helmholtz, 1911, pp. 42f). This is remarkable, given the size of the blind spot. Helmholtz (1911, p. 29) notes “that eleven full moons can be placed side by side along its diameter.” The existence of the blind spot can be conveniently demonstrated with **Figure 2.1**:



[[Figure 2.1](#)] *Blind Spot Demonstrator*

Using **Figure 2.1**, position your right eye directly in front of the **D** and approximately 3.2 times the distance between the **D** and **S**. While your right eye is directly in front of the **D**, alternately move your head towards and away from the screen. You will see the **S** disappear as it is brought into the blind spot and is imaged onto the optic disc of the right eye. By placing the left eye over the **S**, a similar result will occur for the left eye. An alternative, but convenient, way of demonstrating the absence of vision for this part of the visual field is to use a hand-held diode laser pointer and direct its beam at a wall; while maintaining a fixed gaze with one eye open, move the pointer back and forth (laterally). You will see the dot of light disappear and re-appear as it goes into and emerges from the blind spot located lateral to the center of the visual field of the open eye. This illustrates that even a relatively intense light imaged onto the optic disc is unseen.

In addition to the scotoma resulting from the absence of photoreceptors in the optic disc, part of the retinal vascular supply, consisting of the central retinal artery and vein, cover part of the retina and its photoreceptors, except for the avascular region of the fovea (Polyak, 1957, pp. 598-602; also Figures 363, 364, and 365 following p. 606). A consequence of the blood vessels covering part of the retina is a loss of vision for those regions, a phenomenon known as angioscotomas. The fact that we do not normally see these blood vessels seems to be related to the loss of vision associated with stabilized images on the retina which begin fading as soon as the image stabilizes (Riggs, Ratliff, Cornsweet, & Cornsweet, 1953). In the case of retinal vasculature, the vessels are effectively stabilized because they move with the eye during normal

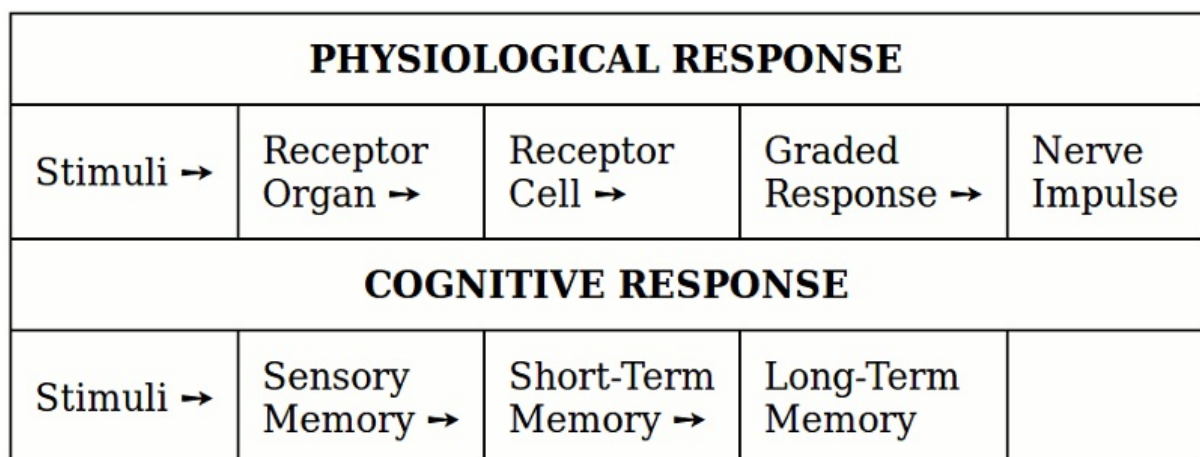
saccades (jerky eye movements from one fixation point to another) and, also, during the small movements (physiological nystagmus) that constantly occur. The scotomas generated by the optic disc and blood vessels may have gone unnoticed because they are, also, located in the periphery of the visual field where visual acuity is significantly lower.

Our sensory awareness of our environment clearly has its limitations, as indicated by the limited range in light wavelengths to which we are visually sensitive and by the corresponding restricted range of audible frequencies that we as humans hear. Pit vipers, among snakes, are sensitive to infrared (heat) portions of the electromagnetic spectrum. Other animals have auditory sensitivity extended into the infrasonic (such as elephants and whales) and ultrasonic (such as bats, some bat-avoiding insects, cats, and dogs) frequency ranges.

Nevertheless, we do have sensitivity for many stimuli that encounter those parts of our body containing specialized cells that are responsive to the type of energy present in the stimulation. These specialized cells are receptor cells, which respond to stimulation electrically through either graded changes in electrical potential or by action potentials (nerve impulses) initiated by the receptor cell itself. In the case of graded potentials (as in vision and hearing), stimulation is transferred to subsequent cells which generate the nerve impulses. Our central nervous system (CNS), composed of the brain and spinal cord, can be tricked through artificial electrical stimulation of a sensory nerve, thereby bypassing the sense organ (as in the case of a cochlear implant) with a consequent imitation of perceived reality. We are, thus, not directly aware of our environment; rather it is the case that we only know what our sensory nerves tell us. I am not, here, suggesting a viewpoint of solipsism (no other minds exist apart from mine), which would indicate that writing a book has dubious value. It is simply the case that what may seem to be obvious is not, when examined, so obvious. Reality is not what our senses provide. It is through consideration of the history of stimulation (our memory) and cognitive elaborations that we make sense of the sensory world.

In order to systematically organize our thoughts (in two ways), **Figure 2.2** serves to indicate, in a simplified manner, the sequence of activity, physiologically (on top) and cognitively (below), of events temporally going from left to right as one perceives the environment. In the physiological response, a stimulus encounters any of multiple parts of the body with most being insensitive to the stimulus encountered. If the stimulus does enter a sense organ containing receptor cells that absorb energy of (i.e., and react to) the stimulus, then the effect is to cause the receptor cell to react electrically

with a graded change in electrical charge from its pre-stimulus condition or, in some cells, to generate a nerve impulse (action potential) that travels over the cell into the central nervous system (CNS). In other cases the graded (generator) potential change serves to stimulate the first neuron, which generates, in response, a nerve impulse. The resulting nerve impulse, however generated, travels over sensory nerves to the brain or spinal cord, which make up the CNS. The brain and spinal cord experience the external world through the succession of nerve impulses entering via sensory nerves. There can be exceptions to this normal sensory input, as in the case of electrical stimulation of the unanesthetized and surgically exposed brain of conscious neurosurgical patients who are awake during (at least part of) the operation. The stimulation is done for diagnostic and therapeutic benefit to the patient and provides reactions indicating functioning of parts of the surgically exposed brain (Penfield and Roberts, 1959).



[[Figure 2.2](#)] *Physiological and Cognitive Response to Stimuli*

The upper part of **Figure 2.2** does not show the CNS, multiple parts of which may receive nerve impulses from the receptor organ. The lower part shows a simplified cognitive model of some of the events resulting from stimulation. More complex cognitive models exist.

Physiological Inputs

Some parts of human anatomy (and, of course, other animals) are particularly sensitive to specific energetic environmental changes (stimuli). These parts, known as receptor cells, are found embedded within a collection of other supporting cells (called accessory organs) which are not themselves sensitive to the stimulation but serve to support and protect the receptor cells within a given sense organ. The receptor cell transduces environmental energy (directly or indirectly) into action potentials (nerve impulses) that travel from

the receptor organ to the central nervous system (CNS), consisting of the brain and spinal cord. Transducers are, generally, devices which convert energy of one type or level into energy of another type or level (e.g., microphones, speakers, lamps, etc.). Thus, the transduced sense organ output in the form of nerve impulses travels over sensory nerves into the CNS, which is aware only of this succession of nerve impulses as they are correlated with other nerve impulses from the same and other senses. Human patients undergoing brain surgery can be awake and conscious while the unanesthetized brain is cut into without feeling pain. Mild electrical stimulation applied to the exposed cerebral cortex may (by its stimulation of localized nerve impulses) elicit verbal expression of memories (“experiential responses” and “interpretive responses”) described as they seem to occur in real time during the operation (Penfield & Roberts, 1959, pp. 45-55). To a large extent, hard wiring of the CNS determines what part (or parts) receive stimulation from specific receptor organs. Damage to either the receptor organ, sensory nerve, or that part of the CNS immediately receptive of the sensory input can result in a modification of sensitivity and consequent loss of awareness of sensory input.

Modifications of vision, for example, can result from damage to the retina within the eye, malfunction of the optic nerve, or damage to the occipital lobe of the brain (where the primary visual cortex is located). In each of these cases, damage can result in a modification of visual awareness, which may or not be conscious. An example of an unconscious instance would be illustrated by the neuropsychological study of individuals with blindsight (Weiskrantz, 1986). Individuals with damage to part of the occipital lobe lost conscious vision of part of the visual field corresponding to the portion of cortex damaged. The result was that, when asked to point to an object (e.g., a book) placed before them within a perimetrically determined blind part of their visual field, they could do so even while being unable to see the object (and were surprised to find they accurately did so). This ability seems to be a consequence, as Weiskrantz and others indicate, of a “two visual systems” response. The striate cortex of the occipital lobe is not the only destination of the fibers of the optic nerve. A recent analysis and discussion of this is provided by Mizzi and Michael (2016). By considering such things as conscious awareness though, we are moving from the physiological realm into the cognitive realm. Apart from visual loss resulting from damage to the occipital lobe, as just described, other parts of the brain, when damaged, may generate a type of visual agnosia called associative visual agnosia in which there is difficulty in recognizing an object visually, although the object may be seen or accurately drawn (Farah, 1990). This type of agnosia, among others, seems to be associated with damage outside the occipital lobe.

Cognitive Inputs

The lower part of **Figure 2.2** illustrates a simplified sequence of theorized events of a cognitive nature that covary with, or are sequelae of, physiological events in the upper part. It will be immediately seen that memory shows up in three varieties: sensory, short-term, and long-term. These forms of memory seem to be primarily distinguished on the basis of temporal durability.

Sensory memory can last up to one-half second (for visual, or iconic, memory) or up to several seconds (for auditory, or echoic, memory). Short-term memory lasts (without rehearsal) up to approximately 30 seconds, and long-term memory, although subject to corruption, may last a lifetime. These separate memory types have been observed and investigated by a combination of experimental psychology laboratory and clinical neuropsychological methods. These memories are the concerns of Chapter 3.

Summary

Humans are sensitive to many things in their environment in the form of light, sound, tactile stimulation, odors, etc., but they are, also, insensitive to infrared, ultraviolet, infrasonic, ultrasonic, and certain gas or liquid chemicals (some of which may be poisonous). Other animals share some of the same sensitivities but may be sensitive to stimuli to which humans are not sensitive.

The sensitivities we have result from specialized receptor cells that perform a function of sensory transduction, converting stimulus energy encountered in the environment into a form usable by the nervous system. Some of these usable sensory inputs may be organized cognitively and retained by the individual as memories. Memories are not uniformly of one type. Instead, there appear to be several kinds of memory, differing in time of initiation, duration of existence, and anatomical locus of action.

Chapter 3 – Memories

Sensory Memory

As mentioned in Chapter 2, there are three types of memories, sensory, short-term, and long-term, primarily distinguished in their temporal durability. Visual sensory memory (also known as iconic memory) can last up to one-half second, whereas auditory sensory memory (also known as echoic or acoustic memory) can last up to several seconds. Although there are other types of sensory memories, I am mainly concerned in this section with iconic and echoic memory.

When, for example, I briefly open my eyes and view my surroundings, I seem to see a large collection of differentiated objects that can be separately named. As I shift my view to another spot in my visual panorama through a visual saccade, the blindness that occurs during the saccade is not noticed. Once in focus at this new spot, it appears that I see many distinguishable things, but, if asked what they are after I close my eyes, I am likely to mention only 4 or 5, although more items seem to be escaping my memory as I complete my responding. This kind of vanishing memory has been studied by George Sperling in the laboratory in a variety of ways, two of which will be described here.

Sperling (1960) used two major approaches in his investigation of memory: one involving a whole report and the other, described by him, as a partial report procedure. Consider the following matrix of letters presented visually for 50 milliseconds (msec):

T	D	R
S	R	N
F	Z	R

The individual is asked to repeat, in their correct position, as many of the letters as they remember. A typical person is able to correctly respond to this whole report request with 4 or 5 correct responses. Sperling found this to be the case with his subjects. He used a second procedure that modified the whole report into what is called a partial report by tachistoscopically presenting the matrix for 50 msec, followed immediately by one of three randomly selected tones indicating which row of letters from the matrix was to be reported by the subject. The tones, 2500, 650, or 250 cps [Hz], indicated the top, middle, or bottom row of the matrix, respectively. Although the tone

occurred after the matrix of letters was presented and removed, the subjects attained a nearly perfect accuracy in their responses, indicating that virtually all of the matrix was remembered for a brief time. Sperling varied the interval between matrix presentation and subsequent tone and found that the memory declined to a level at 1.0 second post matrix that was similar to the correct response level for those tested with the whole report procedure. Similar results were obtained with a matrix of three rows of four letters (or letters and numbers).

A somewhat similar type of sensory memory, christened by Neisser (1967) as "echoic memory" or acoustic sensory memory, lasts longer than iconic memory, namely several seconds. In a way this longer duration is necessary because, in contrast to iconic memory (which can be refreshed by saccadically returning to what has just been viewed), sounds are not recoverable by the listener. Subsequent meaning depends upon the temporal sequencing of auditory components, whether one is deciphering a polysyllabic word or a sequence of sounds in International Morse Code (a single initial dit may represent the start of commonly used characters, such as A, E, I, S, H, 1, 2, 3, 4, 5, period, ?, J, L, P, R, U, V, or W). The word or Morse Code character requires the preservation of the initial and subsequent phonemes for accurate interpretation. Without the additional phonemes or parts of the Morse Code character, the acoustic message is not accurately and unambiguously interpretable.

Attempts to measure the duration of echoic memory are varied, as Neisser (1967) indicates with several examples. One investigation by Darwin, Turvey, & Crowder (1967) approached the issue by using a procedure similar to that used by Sperling (1960) but with letters and numbers presented simultaneously through stereo headphones as different lists to the two ears of human subjects. The task was to identify, following this simultaneous presentation, what was heard in the left ear, or in the right ear, or in both ears. Partial reports were better than whole reports (as in the case of Sperling's findings), although they were not as accurate as iconic memory responses. The partial report extended the duration of echoic memory past two seconds, which suggests that echoic memory is longer than iconic memory.

An Iconic Memory Thought Experiment

Imagine with me that I am sitting with my eyes closed and at a distance of approximately 65 cm (corresponding to a resting accommodative state) from my computer screen. Imagine further that I suddenly open my eyes briefly for a duration sufficient to quickly focus my vision on the contents of the

displayed material on the computer screen before, once again, closing my eyes. Assuming sufficient luminance for good photopic vision and an absence of visual defect, I will probably see a matrix of letters and spaces. The letters are likely to be easily remembered since they are not random but rather appear as parts of words which may be remembered as automatically recoded chunks of information (Miller, 1956). By using random letters (without vowels), Sperling avoided the incorporation of the letters into a smaller number of collective functional memory units called chunks that could be easily remembered. With random letters immediately before me, I am, also, limited in visual input to those letters within a visual region subtending an angle equal to that for objects optically imaged onto the fovea.

Conventional illustrations of vision with macular disease frequently show a central region of the visual field thoroughly obscured with surrounding parts (peripheral vision) relatively clear. In actuality, peripheral vision is less acute and not as clear as such illustrations would indicate. In the case of someone with a healthy fovea (without macular damage), there are unnoticed saccadic movements of the eyes (using foveal vision) that enables sampling into and out of the peripheral area. This gives an illusion (because of not yet faded visual memories from such movements) of having better peripheral vision than is really the case. This seems consistent with our experience of viewing (without macular damage) textual material and experiencing the illusion, as a consequence of unnoticed saccadic movements of the eyes, that other parts of the text are clearly seen. Marmor & Marmor (2010) describe what is more likely seen in their simulations of the effects of macular loss. Clear vision, with or without macular loss, is considerably impaired as one moves a few degrees away from the fovea.

By briefly viewing a matrix of random consonants, prepared by someone else, for approximately one second (either by opening and closing my eyes or making use of an empty single lens reflex film camera with the lens removed and opened to permit use of the shutter timing to provide a time calibrated exposure of the matrix), I can test myself on the accuracy of retained memory for the letters briefly seen. It is not difficult to write a Sperling (1960) emulation computer program that presents a 3 X 3 matrix of random consonants for a controlled time period (e.g., 1 sec), immediately (e.g., within 0.25 sec) followed by either a request to enter all displayed letters in their respective positions (Sperling's "whole report") or, after a provided cue indicating which row is to be recalled, a request to enter those letters in the designated row (Sperling's "partial report").

Short-term Memory (STM)

In order to remember something for a longer time than that provided by sensory memory, some additional functioning seems to be needed. John Brown (1958) and Lloyd and Margaret Peterson (1959) independently investigated and discovered what has come to be known as short-term memory (STM). If I am asked to remember something new, such as a word (e.g., in another language) or a telephone number, my experience is to mentally rehearse it for a brief period of time. True, there are instances of verbal material that may be remembered without conscious effort, but foreign words and telephone numbers do not seem to fall into this category of instances. An analogous verbal task is to remember a short random sequence of letters, specifically consonants (to avoid the recoding that concerned Sperling). Remembering the sequence JQG would normally and effectively be done by rehearsing the sequence (and, perhaps, elaborating it by means of some mnemonic device) over the time course of several seconds. This will increase the probability of subsequent recall. If I am prevented from rehearsing a three-letter consonant sequence (abbreviated as CCC), the probability of recall is reduced.

Peterson and Peterson (1959) prepared an experimental task that required subjects to, upon hearing a “consonant syllable” consisting of three consonants (CCC), immediately count backwards by successively subtracting either 3 or 4 from an initial number during a designated time period called the recall interval. The recall interval was, for a given trial, either 3, 6, 9, 12, 15, or 18 sec. The subtraction task served to interrupt rehearsal during the recall interval. After a red signal light flash indicated the end of the recall interval, there was a so-called latency period that lasted until the subject vocally recalled the consonant syllable. 15 sec after the subject’s response, a green signal light flash indicated the start of the next trial. The two signal lights (one red and one green) were small lamps mounted on a black box that was positioned on a table in front of the subject.

In their description of results, Peterson and Peterson (1959, Figure 2) provide a collection of curves, one for each recall interval, showing “proportions of correct recalls as cumulative functions of latency.” Each curve approaches an asymptotic level indicating the final proportion of correct responses under that recall interval. An estimation of these values from an inspection of their Figure 2 suggests the following values in **Table 3.1**:

Recall Interval (sec)	Percentage Recalled (%)	Recall Interval (sec)	Percentage Recalled (%)
3	77	12	22
6	55	15	10
9	32	18	8

[Table 3.1] *Percentage of Consonant Syllables Recalled as a Function of Recall Interval.* Data estimated from Peterson and Peterson (1959, Figure 2).

The amount retained in memory without rehearsal is considerably reduced after a few seconds (>90% lost or <10 % retained at 18 sec). Rehearsal permits one to preserve fragile memories for a time period sufficiently long to recode (by chunking or some other means) verbal materials that may, subsequently, be consolidated into a permanent form of memory.

Chunking (or Recoding)

George A. Miller presented an invited address before the Eastern Psychological Association entitled, "The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information," which was subsequently published (Miller, 1956). In this presentation he describes, through data-based examples from published studies, some instances of memory limitations prevalent among humans. Specifically, he suggests that humans are capable of remembering approximately seven discrete verbal items, or chunks, at a single time (± 2). The binary number 0110101, for example, provides a greater memory challenge than its recoded equivalent decimal value of 53. Miller maintains that humans, in order to compensate for what appears to be a cognitive limit on our memories, automatically recode by reducing greater memory loads down to seven, or fewer, chunks. This may provide the basis of many effective mnemonics that are used to assist memory.

Long-term Memory (LTM)

Those sensory memories and short-term memories that survive may be

incorporated into long-term memory, a type of memory for events that happened hours, days, or years ago and are preserved (accurately or inaccurately) in our memory permanently (unless lost through physical, chemical, or disease-induced damage to the brain). The process by which this preservation is accomplished is called memory consolidation, and its product is called, variously, a memory trace or engram. The engram is a theoretical (or hypothetical) construct that is believed to be some kind of change, within the brain, that remains and is available for subsequent retrieval as an accessible memory. The nature of the change, depending upon the theoretical construct, is either chemical (e.g., a modified protein), a change or growth in synaptic structure within the nervous system, or both.

The search for the elusive engram has been scientifically active for the past century. One notable instance of a programmatic series of investigations is the work of Karl Lashley (Lashley, 1929), who was unable to find a specific cortical location that seemed to be responsible for maze learning in rats. He concluded, based on findings that learned behaviors deteriorated proportionately with the amount of cortex lesioned in experimental animals, that the engram (if it uniquely existed) was distributed across the cortex instead of in one particular location. Subsequent studies have attempted to find what Lashley did not (see Thompson, Donegan, & Lavond, 1988 for more information).

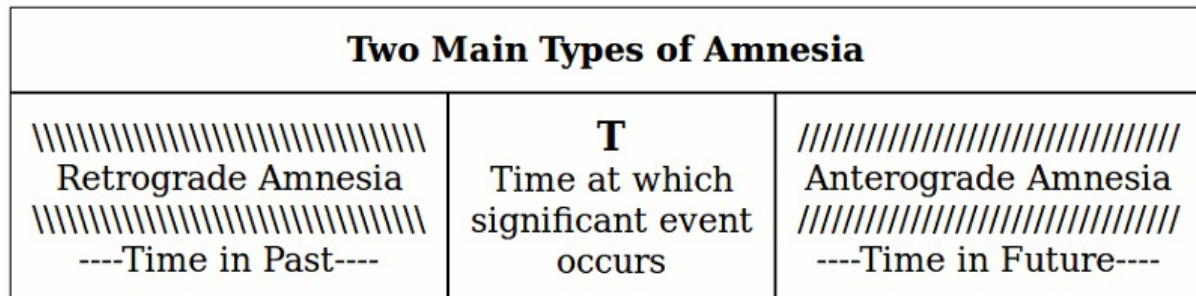
When one tests memory with successful recovery, two separate circumstances must have occurred. First, there must be some incorporation by the organism of that which is remembered. This incorporation into a permanent (or durable) memory is called consolidation. The second circumstance is that the memory must be successfully retrieved. Failure of either circumstance (or both) results in amnesia for events which would, otherwise, be remembered. Many events can cause amnesia, including concussions (resulting in a loss of consciousness), drug effects, electroconvulsive shock, strokes, and certain diseases. Noted diseases that result in amnesia include Alzheimer's disease, Lewy Body Dementia (LBD), major or minor seizures, Parkinson's disease, Korsakoff Syndrome (vitamin B1 deficiency), among others. The aforementioned causes of memory failure are generally distressing to the person with memory loss. There are, also, more benign, but scientifically interesting, causes of commonly experienced memory failure. We do not recall most events that occur during sleep (e.g., body movements, breathing activity [including sleep apnea], and most dreams). Students may fail to recall significant items on a quiz because of inadequate study. A missing memory may result from inattention to appropriate stimuli in the past.

Retrograde and Anterograde Amnesia

Before updating Lashley (1929), let me distinguish between two problems that may account for a failure of memory. Although there are customarily several types of amnesia, I will consider two major types. Consider a timeline that includes a succession of events, some in the past and others in the future. Let **T** denote that moment separating the past from the future and, at which time, a significant event occurs. *Retrograde amnesia* is loss of memory for events prior to **T**, usually for a period of time up to approximately two years. In some cases, depending upon locus and extent of brain damage (Squire, 2006), this time period can be much longer. As one approaches **T**, there is increasing loss of memory. Retrograde amnesia occurs following a discrete (usually physically or chemically traumatic) event resulting in sudden loss of consciousness (such as a concussion). Over a period of up to about two years following **T**, some, but not all, of the lost memory may return. The period of time during which there is retrograde amnesia includes many events which are remembered mixed with those not remembered, i.e., the memories are patchy with the patchwork quilt of memory being increasingly filled in over time following **T**. If the memory has not been recovered within approximately two years, it is likely to have been permanently lost. If the person experiencing retrograde amnesia is confronted with accounts of what had happened from other people, an artificial memory of some of the events may be constructed in a process called confabulation, which may appear to be a genuine memory. Confabulation, whether done by alcoholics attempting to mask their condition or by individuals without a memory defect trying to recall certain events through normal recall activity, is a normal cognitive process. Memory inaccuracy may be increased through the intrusion of errors that are, in turn, rehearsed and effectively consolidated as apparent genuine memory components. This problem exists for those interpreting not only memories following brain injury but also for “normal recall” of events in eyewitness testimony (Wells, 1993).

A second type of amnesia is called *anterograde amnesia*. With reference to the point in time **T**, a person with anterograde amnesia experiences (much) greater inability to learn and remember new things following **T**. In a pure case there is no loss of memory for events prior to **T**, only for new things. Examples would include names of people you meet at the next party, new words you encounter while learning a foreign language, what you had to eat during a meal earlier today, or whether or not you have eaten today. Some of these examples represent benign memory loss, but pathological anterograde amnesia includes severe inability to remember new events or things to the point that it interferes with life. Clinical cases are exemplified by vascular

dementia and Alzheimer's disease. In general, both retrograde and anterograde amnesia may be present in a given individual with one type being much more obvious. **Figure 3.1** illustrates the temporal relationships between retrograde and anterograde amnesia.



[[Figure 3.1](#)] *Relative Time Effects on Memory for Retrograde and Anterograde Amnesia.* There is greater retrograde memory loss for events prior to, but close in time to, **T**. Anterograde amnesia loss is relatively constant and may be unimproved following time **T**.

Consolidation of Transient Memories into Long-term Memory

The mechanism by which sensory memories and short-term memories are transformed into long-term memory is called *consolidation*. Theoretically, such a mechanism installs the engram somewhere in the body, presumably within the nervous system. It was this installed component of memory that Lashley (1929) unsuccessfully investigated. Although his search continued, others have attempted to find the engram and its anatomical location. An indirect way to approach this is by determining the time period during which the engram is formed. An early and suggestive study of this type is that of Duncan (1949).

Retrograde amnesia is a common occurrence following electroconvulsive shock (Squire, 2006). In an elegant experiment investigating the time related development of retrograde amnesia, Duncan (1949) used albino rats as experimental subjects in a carefully designed learning situation employing a two-compartment box. One half of the box (painted black with a floor made of one-quarter inch steel rods) served as the shock compartment; the other half of the box (painted white with a floor made of wire mesh) served as the safe (no shock) compartment. Between the two compartments was a partition through which the animal could move between the two compartments. The subject in each experiment was initially placed into the shock side of the compartment, but no shock was delivered. After entering the safe side, it was moved back into the shock side. A 100-W lamp was used to illuminate the safe white end of the enclosure in order to keep the subject in the shock

compartment until a 10-second "conditioned stimulus" indicating an imminent foot shock was presented. Delivery of the foot shock resulted in the subject escaping to the safe side. After 10 sec in the safe side, the subject was removed for a duration determined by the experimental condition. As Duncan describes it:

The animals were divided into eight experimental groups and a control group. The experimental groups, referred to by the time which elapsed between running from the grid and application of electroconvulsive shock, were as follows: a 20 sec., 40 sec., 60 sec., 4 min., 15 min., 1 hr., 4 hr., and 14 hr. group. The control group was run in the same way as the experimental groups but received no cerebral shock.

The cerebral electroshock or electroconvulsive shock (ECS) consisted of 85 VAC applied for 0.2 sec via saline soaked electrodes attached to the ears and, thus, bilaterally across the cerebral hemispheres. All of the subjects in the 8 experimental groups, following the escape or avoidance into the safe side for a period of 10 sec, were given (after the duration expired for the experimental condition) an ECS, only one of which was unsuccessful. Animals in each of the experimental groups were given an ECS trial each day on each of the 17 days and no ECS on day 18. The control subjects were monitored without ECS on each trial for all 18 days. Anticipatory responses (avoidance responses) for each subject on each day in each group were recorded. **Table 3.2** summarizes the main findings.

EXPERIMENTAL GROUP	MEAN ANTICIPATORY RESPONSES	EXPERIMENTAL GROUP	MEAN ANTICIPATORY RESPONSES
20 sec	2.54	1 hr	12.33
40 sec	5.85	4 hr	12.16
60 sec	8.00	14 hr	12.66
4 min	9.11	Control	12.00
15 min	10.20		

[Table 3.2] *Number of Mean Anticipatory (Correct) Responses as a Function of the Delay between Moving into the Safe Side and Consequent ECS .*
(Adapted from Duncan, 1949)

As **Table 3.2** indicates, the learning of a correct anticipatory response attained

an asymptotic level somewhere between 4 minutes and 1 hour. This suggests a consolidation of learning somewhere during that interval in which a fragile neuropsychological activity, along the lines of Hebb's (1949) speculative concept of cell-assemblies, would temporarily maintain the learned behavior before a more permanent neuroanatomical change in the form of synaptic connections or chemical modification occurs.

Thus far I have indicated temporal characteristics of the development of memory in the organism. For ethical reasons the kind of study done by Duncan (1949) is not possible with humans, although clinical observation of retrograde amnesia following therapeutic applications of ECS provides suggestive and similar results. The fundamental point is that there is a period of time, apparently required, for a transient memory to become transformed into a durable form, one which can withstand the disruptive effects of ECS. Such memories, although possibly incorrect in detail, are relatively permanent. Not completely resolved is the question as to why retrograde amnesia occurs. Is the failure to remember a consequence of the inability to retrieve a memory which is there, i.e., a retrieval defect? Or was the memory never, because of failure to consolidate, installed to begin with, i.e., a storage defect? In retrograde amnesia, the time period before **T** in which some long-term memories (LTM) are no longer available tends to shrink over time from years to months, from months to weeks, and from weeks to days. As this shrinkage occurs, the long-term memories that were affected by **T** (by possibly disrupting their retrieval) and are farthest away in time from **T** are (if recovered) recovered first. This process of recovery of long-term memories and consequent shrinkage of the retrograde amnesia continues until a period of time before **T** is reached in which there may be no more long-term memories to recover. This is possibly because the memories that happened during this particular period of time (as Duncan's study suggests) were not around long enough to be consolidated into long-term memory because **T** occurred before the process could be completed. In the case of therapeutic ECS, it appears that failure to consolidate and failure to retrieve probably both happen.

In the first three sections of this chapter, I have described sensory memory for vision and hearing (other senses have been studied less), which lasts anywhere from less than a second to several seconds and contains, during its brief presence, a fairly large amount of information. I, then, described what is called short-term memory (STM), which lasts (without rehearsal) up to approximately 30 seconds and contains a limited (7 ± 2) number of chunks of information. The memories, which last a lifetime, form what is called long-term memory (LTM). I wish to turn from these temporal concerns to the

question of what changes in the body (and where) when a memory is formed. This brings us back to the engram or the location of the memory trace. As Lashley (1929) found, the answer has been elusive, but during the 1950's and later some significant developments occurred.

The Medial Temporal Lobe and Memories

Although memory impairment has been associated with histologically identified damage to parts of the diencephalon, such as the medial dorsal thalamic nucleus, other thalamic nuclei, and mammillary nuclei (Squire, 2006; Squire and Zola-Morgan, 2011) associated with Korsakoff's syndrome, much attention has been directed toward the hippocampus and other structures within the medial temporal lobe since the initial description of the patient H. M. by Scoville and Milner (1957). The consequent memory difficulties of H. M. and, to a lesser extent, of several other patients receiving therapeutic bilateral medial temporal lobe resections have revealed an anatomical correlate to the distinction between the roles of short-term and long-term memory. Of the eight bilateral medial temporal lobe resection patients (two other patients received other operations and, reportedly, did not experience memory changes) described by Scoville and Milner, I will devote my attention to those identified as H. M. and D. C. Both of these, following the operation, had above average Wechsler Full Scale IQ's and below average Wechsler Scale Memory Quotients. Surgical access to the medial temporal lobes was accomplished via a supra-orbital trephine and varied in extent across patients. The operations on H. M. and D. C. were done for different reasons. H. M. was a 29-year old high-school graduate suffering from increasingly severe minor and major epileptic seizures that were medically intractable, preventing him from working. It was believed that the operation could be of benefit to the patient and was conducted with the agreement of the patient and his family. D. C. was a 47-year old physician with paranoid schizophrenia and violent behavior. "Insulin and electro-shock" therapy had been unsuccessfully tried. H. M.'s operation consisted of an excision of the medial temporal lobe from the mesial surface to the temporal horn of the lateral ventricle with the posterior limit 8 cm [later determined on the basis of MRI to have been 5 cm (Squire, 2009)] from the tips of the temporal lobes. D. C.'s operation proceeded somewhat similarly with excision of the medial temporal lobe from the mesial surface to the temporal horn of the lateral ventricle and posteriorly 5.5 cm from the tips of the temporal lobes, but with additional orbital undercutting.

Neuropsychology of H. M.

Recognizing that there is functional specificity for parts of the medial temporal lobe, I will refer to this anatomical region of the brain as a unitary portion of the brain. The specific functions of its individual parts have yet to be thoroughly established through careful neuropsychological analysis. Even with the posthumous microtome sectioned brain of H. M. (very generously arranged by H. M. and his family before his death), lesioned (or resected) areas found may be difficult to associate with behavioral deficiencies experienced when living. They do, however, suggest things to be alert to with other individuals who have brain damage in similar places.

Prior to his bilateral medial temporal lobe resection, H. M. was cognitively relatively normal with an above-average IQ. Following the operation his IQ actually increased, presumably because of the relaxation of his anticonvulsant medication (since the operation did reduce the frequency and severity of his seizures), although his Wechsler memory quotient was significantly reduced. As described in several sources (Scoville and Milner, 1957; Corkin, 2002; Squire, 2006; among others), H. M. experienced severe anterograde amnesia.

H. M.'s memory difficulties seem to be of a declarative memory loss in which one has difficulty with consciously describable facts about their experiences and encounters. Specifically, it included failure to learn or recognize hospital staff, to know where he currently lived (although he could describe where he previously lived, without awareness of a recent move from that location), where commonly used items were located, an absence of awareness of magazines previously read, and meals previously eaten (or that he had eaten 30 minutes earlier). He was able to learn a procedural perceptual motor memory task (mirror star tracing, which requires that one trace between the borders of a star while observing it, not directly, but via a mirror image of it) over the course of three days, although on days 2 and 3 required explanation about what was required since he had no recollection of having encountered the task before. He did, however, exhibit an ability for normal perceptual motor learning. He could remember for a period of 15 minutes a three-digit number by actively rehearsing and using a personally developed mnemonic; the number and memory of the task were lost after a brief distraction (Squire, 2009). In addition to anterograde amnesia, there was noticeable retrograde amnesia. His memory performance on the Famous Faces II test, given in 2000, was at or above normal for tested decades in the 1920's and 1930's but below normal for the 1950's and later (Corkin, 2002).

Fundamentally, H. M. was unable to consciously learn any new factual information, either what he was told or what he experienced in his own daily life apart from procedural knowledge in the form of perceptual motor skills.

The part of the brain primarily responsible for the storage of this declarative memory has been, based on subsequent research (Squire, 2006), the hippocampus. This brain structure was removed with other parts in the medial temporal lobe resection. The hippocampus is not the only part of the brain which, when damaged, can lead to anterograde amnesia; the mammillary bodies (and adjacent structures) of the diencephalon can have similar consequences if damaged from thiamine deficiency in Korsakoff's syndrome. The diencephalon was not affected in the series described by Scoville and Milner (1957).

Neuropsychology of D. C.

In contrast to the systematic study of H. M. which lasted for decades until his death (and continues following his contribution of his brain for neuroanatomical research), less seems to be known about D. C., the 47-year-old physician who was combative, violent, and schizophrenic. He was unsuccessfully treated medically, and it was determined that a bilateral medial temporal lobe resection with additional orbital undercutting be done. The paranoid component of his schizophrenia was preserved postoperatively, but the aggressive and hostile nature of his preoperative behavior was no longer present. In its place was, as indicated by the hospital staff, considerable confusion about where he was and the identity of people he encountered. He was examined a year and eight months after the operation by Milner, who found him to be above average with a Wechsler IQ of 122, although the Wechsler Memory Scale memory quotient was 70, and he did not know the name of the examiner nor the hospital (after being repeatedly told). His memory seemed to vanish when distracted, and he did not know that he had undergone a brain operation, although he "could give minute details of his early life and medical training (accurately, as far as we could tell)" (Scoville and Milner, 1957).

Summary of Memory and the Temporal Lobe

The memory deficit in D. C. was similar to that experienced by H. M. There was declarative memory for events previously consolidated but an inability to transfer new memories to long-term memory. One consequence of these findings is that the medial temporal lobe is now only carefully operated on unilaterally for fear of the existence of unknown preoperative damage in the contralateral lobe. This damage risk can be reduced by using a memory extension of the Wada test (e.g., a unilateral intracarotid injection of sodium amobarbital, which turns off the ipsilateral hemisphere, including its motor cortex, with obvious paralysis of the contralateral limbs) in which the

conscious patient is provided with verbal and pictorial material when the paralysis occurs and is tested a few minutes later for memory of the previously presented material. Memory preservation indicates that the contralateral medial temporal lobe is intact.

As Squire (2009) points out, the results of temporal lobe resections and later investigations of the hippocampus established for memory function an analogous brain localization similar to the established functions of motor, visual, auditory, and language activity. The long-term memories are not uniquely and completely stored in this part of the brain, since its bilateral removal reveals subsequent recall of earlier memories. For three successive days, H. M. was given a perceptual motor task (mirror star tracing). Although not remembering on days 2 and 3 that he had done the task before, he, nevertheless, exhibited a normal pattern of learning improvement. This shows that memory is, in some respects, a multiple function and, correspondingly, functionally localized in different brain areas. The study of H. M. and others with memory difficulties has revealed the differences between declarative memory (conscious memory of events and facts) and non-declarative memory, consisting of “skills and habits, simple forms of conditioning, emotional learning, priming, and perceptual learning, as well as phylogenetically early forms of behavioral plasticity such as habituation and sensitization” (Squire and Wixted, 2011). This distinction, based on human and animal studies, has indicated the reality of multiple memory systems.

Squire and Wixted (2011) describe a number of cases of acquired neuropsychological deficits (typically resulting from closed head injuries) with MRI determination of the parts of the brain that were damaged. Generally, in each case of acquired achromatopsia (total color blindness), prosopagnosia (face blindness), and amusia (inability to recognize familiar music), there was retrograde amnesia for past perceptual experiences (e.g., green grass, when viewed, appeared grey) and anterograde amnesia for new perceptions. New brief musical selections, when repeated to a person with amusia, were not recognized as repeats. The neuropsychological deficit was, however, specific (i.e., amusia and not prosopagnosia) and was related to the MRI-indicated region of the brain (neocortex) damaged.

A review of the neuropsychology, neural imaging (e.g., fMRI and PET scans), and theoretical involvement of parts of the medial temporal lobe, prefrontal cortex, and other parts of the temporal lobe in attempting to localize specific regions of the brain responsible for specific cognitive deficits (e.g., loss of episodic memory or semantic memory) is provided by Becker and Overman (2002). They describe quantitative scanning methods that can be (and are)

used to relate cognitive deficits occurring in frontotemporal lobe dementia, Alzheimer's disease, and dementia syndromes, including Lewy body dementia, Korsakoff's syndrome, Parkinson's disease, and Huntington's disease, among others.

Summary

In order for me to remember something, I first must encounter stimuli paired with other stimuli or with time. This is required for sensory memory to register the memory components. Even so, only a fraction of what I encounter survives long enough to be incorporated into short-term memory with its limits of approximately seven discrete items (or chunks) of information. Rehearsal, generally, permits the transfer from a transient memory into a consolidated and more permanent long-term memory store. Accomplishing this requires the senses (sensory memory) and various brain areas (for short-term and long-term memory). Those areas of the brain include, in particular, the medial temporal lobe (including the hippocampus), parts of the diencephalon (thalamus and hypothalamus), other parts of the temporal lobe, and the frontal lobes. As a consequence of animal studies and extensive neuropsychological examination of human patients with some of these areas being non-functional because of accidental or therapeutic lesions, strong associations have been found between some areas and memory dysfunction.

Chapter 4 – Attentional Limitations and Selective Perception

When I enter a room, I am confronted with a multitude of potential stimuli. There are things that I see, hear, possibly taste, smell, and touch in addition to a large number of stimuli, as indicated in Chapter 2, to which I am insensitive, as well as distorted stimuli mentioned in Chapter 1. Nevertheless, of those stimuli that I notice (and am sensitive to), many are transient, as indicated in Chapter 3, thus leaving me with a subset of sensory memory contents containing stimuli which I selectively perceive. Some of these contents survive a few seconds, with only a small number (in accordance with Miller's 7 ± 2 limit) surviving longer. This last component of selective perception is called attention. I have introduced it in this, admittedly convoluted, way to indicate how we selectively perceive our environment.

In order to selectively perceive (or attend) to parts of our environment, we actively exclude some and inactively (without awareness) exclude other environmental stimuli. The sensory residual, at any given time, might be called the attended present. Within a few seconds (beyond the limits of short-term memory and far beyond the limits of sensory memory) the attended present, without rehearsal, vanishes. It is through rehearsal (possibly automatic, if not intentional) that some neurological action converts our transient memory of the attended present into a more durable form.

Shadowing

As an example of actively attending to one aspect of our environment while effectively excluding another part of nearly the same environment, consider the following experimental arrangement. A person places a pair of stereo headphones on with the capability of presenting two messages to the ears, one to the left ear and a separate message to the right ear. Each message is a long string of textual material. The experimental subject is required to attend to one of the message strings entering, e.g., the right ear and is required to vocally say each word heard as it is presented, thus ensuring attention to the message entering the right ear. After several minutes the subject is tested for memory for the content of the message presented to the unattended left ear. This technique, known as the shadowing task, was introduced by Colin Cherry (Cherry, 1953) and has been used with a number of variations since (e.g., Moray, 1969). In general, the consistent finding is that under the circumstances of the original arrangement, very little of the message

presented to the unattended ear is recalled. Apart from the person's name delivered to the unattended ear, virtually nothing else is recalled, even a temporary change in language from English to German or from English to French goes unnoticed. The person does, however, notice his or her name or a tone delivered to the unattended ear, but little else.

Multitasking

Given the attentional demands provided by the shadowing task and its diminished memory consequences, there is an indication that attending to multiple ongoing activities simultaneously might be increased in difficulty. In modern life, with its multiple distractions, we find ourselves surrounded by a collection of informational sources competing for our attention. If the number is small and not too complicated, we frequently operate under the conscious impression that we are able to monitor each source, either simultaneously or through attentional switching, and receive all (or nearly all) of the information confronting us. Because of the general principle that we may not know what we do not know or perceive, our ability to receive and react appropriately to all of this informational input—a set of behaviors called multitasking—may be at least partially an illusion. This is supported by additional evidence provided by the shadowing experiments.

Multitasking is frequently defined or described as doing two or more things at the same time. This is not accurate. One can walk and talk at the same time without a loss of functional competence. Instead, the term seems to be reserved for instances in which one task has a cognitive load that precludes another task, with its cognitive load, from effectively being performed at the same time. An example of multitasking, which has been studied and is closely related to the shadowing task, is the cocktail party problem, named by Colin Cherry as the “ability to listen to, and follow, one speaker in the presence of others” (Cherry, 1957, p. 278). Because of the “exceedingly contrived” nature of tachistoscopic visual stimulations, as Kahneman (1973, pp. 112-113) describes it, the emphasis has been on auditory selective attention in experimentally studying and formulating theories or models about the phenomena. Kahneman describes evidence for and against several filter and other models of selective perception with emphasis on the auditory cognitive inputs. He summarizes several studies emulating one aspect of the cocktail party phenomenon, noticing one's name as a component of an unattended string of words in the presence of several conversations (Kahneman, 1973, p. 117). He describes some work by Neisser in which subjects were instructed to ignore words printed in red that were located below each line of vocalized

text. They were more likely to notice their names than other words in the unattended category.

A more general approach to the question of the role of cognitive load on perceptual inputs involving multiple senses has been raised in the applied area of human factors. Consider, for example, the possible distracting effects of cell phone usage while driving. The prevalence of cell phones in everyday life suggests a correspondingly high everyday use, both inside and outside moving vehicles. If the use inside a moving vehicle involves the driver of the vehicle, a question arises about the safety of the driving. I will consider the case of a driver communicating vocally on a cell phone (and not texting). There are at least two possible contributors to impaired driving while concurrently using a cell phone. The first is reduced visual input that will occur while briefly looking away from the road and toward the phone. As indicated in Chapter 3, visual acuity drops quickly as one moves a few degrees from that part of the visual field imaged onto the fovea (Marmor & Marmor, 2010). The second contributor is the possible distracting role of an increase in cognitive load provided by attending to both the road ahead and, also, the conversation.

Strayer, Drews, & Crouch (2006) comment with regard to driving while using a cell phone that:

For example, drivers are more likely to miss critical traffic signals (traffic lights, a vehicle braking in front of the driver, etc.), slower to respond to the signals that they do detect, and more likely to be involved in rear-end collisions when they are conversing on a cell phone (Strayer et al., 2003). In addition, even when participants direct their gaze at objects in the driving environment, they often fail to “see” them when they are talking on a cell phone because attention has been directed away from the external environment and toward an internal, cognitive context associated with the phone conversation.

These observations are, however, based on retrospective investigations with known and unknown confounding variables that may contribute to inattentiveness. They mention studies that found an association between cell phone use and vehicular accidents but point out that the association alone is not sufficient to ascribe a causal “link” to the cell phone use. In an experiment described in this report with 40 subjects comparing alcohol intoxicated (0.08% wt/vol), cell phone use, and baseline (neither intoxicated nor using a cell phone) driving in a PatrolSim driving simulator, Strayer, Drews, & Crouch (2006) found elevated risk factors for cell phone use, as well as for

drunk driving, over baseline conditions. Different measured driving variables (e.g., brake reaction time, speed, following distance, etc.) contributed to the elevated risk for cell phone and intoxication conditions. They found no difference between hand-held and hand-free cell phone operation and concluded that the risk elevation was likely due to “the diversion of attention from the processing of information necessary for the safe operation of a motor vehicle.”

Change Blindness

In contrast to neurologically induced deficits such as visual agnosia (previously described in Chapter 1), change blindness is a term used to describe unnoticed changes in the visual field with temporarily modified visual content. Basic research concerns (e.g., what variables differentially contribute to the occurrence of change blindness?) and, also, applied research investigations (e.g., what role does change blindness play in driving safety?) have been focuses of experimental investigations. Some of the basic science variables include the role of saccades, location of change target in the visual field, occurrence of temporal discontinuities in the visual field, duration of disruption in a discontinuous visual field, and the occurrence of external stimulation (e.g., transcranial magnetic stimulation over the posterior parietal cortex) of parts of the brain.

Successive movements of the eyes directed to different parts of the visual field, as in the case of reading, are accomplished through saccadic (or jerky) movements of the eyes. During these saccades vision is effectively blind, and the perceptual view is one of successive snapshots of the overall visual scene with an absence of blurring (or smearing) as the eye stops moving when its target is imaged onto the fovea. This is in contrast to the blurred image obtained by a camera that is moved while the shutter is open. A similar blurring is obtained for the eye if a brief mild pulsatile force is applied laterally to the open eye as one views a visual scene (e.g., printed text).

Interestingly, the occurrence of these saccadic eye movements occurs without conscious awareness (except for the arrival of relatively clear vision for a new part of the visual field). A simple way to experience this limited awareness is to stand before a mirror and alternately shift one’s gaze from one eye to the other. You will not notice the movement of the eyes, only the slight change in scene. The eye movements that occur can be easily monitored by video recording them with a digital camera (or a cell phone) aimed at the reflected mirror image of your shifting gaze.

Inattentional Blindness

Early work on change blindness considered (and investigated) the role of saccadic interruption on the failure to notice even large scene changes. Later studies used a blank screen interposed between separate scenes differing in visual content (Simons, 2000). As Simons indicates, the changes range from relatively minor (replacement of a soda bottle by a box in a brief motion picture) to the replacement of an actor by another actor in a filmed action sequence. Simons & Chabris (1999) describe an experiment involving a related phenomenon called inattentional blindness, suggesting a kind of cognitive blindness resulting from insufficient attention to all of a visual scene. Their experiment was based on some earlier work by Neisser (1979) and demonstrated that somewhat significant visual events may be missed when a person is attending to parts of a complex scene. As a follow-up to Neisser's work, Simons & Chabris found, among other results, that as a part of a 75-second video, a woman covered by a gorilla suit walking for 5 seconds across a field of six basketball players, whose passing behavior was mentally monitored for later reporting, was noticed (overall) 44% of the time. Another part of the experiment, replicating some of Neisser's work, using a woman with an umbrella instead of wearing a gorilla suit, found a greater percentage (overall, 65%) noticing this unexpected event. In each of the 16 separate conditions described by Simons & Chabris (1999), the unexpected event (woman with an umbrella or wearing a gorilla suit) occurred within the same visual region as the players being monitored. Nevertheless, the unexpected event was missed a significant number of times.

Inattentional Amnesia

Why does this absence of awareness of a significant part of the visual scene occur? Wolfe (1999), considering the sensory memory phenomena involving vision described by Sperling (described in Chapter 3), suggests an amnesic effect for much of what we see. He provides some empirical support for this view, although Simons and Chabris favor inattentional blindness to be a better explanation because subjects are tested immediately after for any memory of an unexpected event. Wolfe is, however, talking about a memory failure that occurs within a period of up to one second at a maximum before disappearing (sensory memory). The immediate test would still follow the expiration of sensory memory. A stronger indication of the inattentional blindness loss is provided by their observation that "when people notice the unexpected event in this task, they sometimes smile or laugh; non-noticers show no outward signs of detection."

Summary

Given that the amount of information we receive through our senses (excluding stimuli because of insensitivity, as described in Chapter 2) that bias our awareness (as described in Chapter 1) or that fail to be retained because of memory limits associated with sensory memory and short-term memory (as described in Chapter 3), we find that our attended present in conscious awareness is highly circumscribed. The additional limitations, described in this chapter, imposed by shadowing, multitasking, change blindness, inattentional blindness, and inattentional amnesia suggest that we are, despite the illusory appearance of things, barely aware of our environment. In the next chapter I describe what might be the antithesis of this view. That is the view that we have awareness of our environment as a consequence of nonsensory or extrasensory perception.

Chapter 5 – Extrasensory Perception

This chapter briefly describes some of the historical findings in psychical research with emphasis on extrasensory perception and problems of possible sensory leakage contaminating results. Additionally, an in-class educational experimental investigation of the presumed phenomenon of precognition was conducted (and described in detail here) with a total of 183 separate consecutive classes. Results were consistent with chance expectations. In the case of strongly non-chance results (reported by others), the popular view that the occurrences of such highly improbable results suggest paranormal happenings is viewed here as only one explanatory possibility. Upon analysis, it is shown that highly improbable events occur very frequently but go unnoticed.

Introduction

Events happen. Rare events happen rarely (by definition). In either case, probably most events of either type can be accounted for (explained) post hoc via known principles or laws of physics or other sciences. Paranormal phenomena, such as telepathy, clairvoyance, precognition, and psychokinesis, are, in contrast, potentially phenomena for which explanatory principles appear inadequate or nonexistent. The first three of these, being perceptual in nature, are called extrasensory perception (ESP). Several questions arise concerning paranormal phenomena:

1. Do they occur?
2. Can they be experimentally replicated by other researchers in independent laboratories?
3. What exactly signifies a paranormal occurrence?

In reverse order, question 3 will be dealt with in this chapter in the Discussion section. Question 2 has been considered by those who favor the reality of paranormal phenomena and, also, those who do not. The psychologist Gardner Murphy (1958) summarized the status of the area:

The fundamental rule in laboratory science is that you truly have captured a phenomenon and begin to understand it only when you can so fully specify the conditions which engender it, that you can yourself make it happen again and again, and other qualified workers can do the same. We do not, for the most part, even attempt this in parapsychology.

And, similarly, physicist P. W. Bridgman (1956) stated:

ESP, with its statement of nonchance, but with its utter failure to exhibit any regularities or to perform a single repeatable experiment, is the only instance of which I am aware in which a serious claim has been made that nonchance should be capitalized simply because it is nonchance.

These two views, one by Murphy (a believer in ESP) and the other by Bridgman (a skeptic), are consistent with the position that, as of the mid 1950's, no successful interlaboratory experimental replication of parapsychological phenomena had been demonstrated. Since then Rhine and Pratt (1957), Thouless (1972), Berloff (1977), Rhine (1977), Hansel (1966), Milton and Wiseman (1999), Storm and Ertel (2001), and Bem (2011) provide historical reviews and critical evaluations of the evidence for and against paranormal phenomena. Coover (1917), Pratt, et al., (1940), and Rhine (1977) provide historical accounts of the work done prior to 1900. Hansel (1966) provides a skeptical description and analysis of many of the classic studies of ESP (see also Kennedy, 1952). Rouder and Morey (2011) evaluate Bem's (2011) approach. A critical evaluative review of more recent literature has been provided by Druckman and Swets (1988), which concludes "In the committee's view, the best scientific evidence does not justify the conclusion that ESP—that is, gathering information about objects or thoughts without the intervention of known sensory mechanisms—exists" (Druckman and Swets, 1988, p. 207). This does not state that ESP does not exist (or occur)—only that it has not been scientifically established. The status quo of the mid 1950's, nevertheless, arguably remains.

This brings me to question 1, namely "Do they occur?" I will devote my attention to telepathy, clairvoyance, and precognition, since each of these presumed phenomena involves perceptual knowledge obtained through mechanisms currently unknown. Contrary to some popular ideas, these unknown mechanisms do not include one or more senses hitherto undiscovered. Although telepathy and clairvoyance are both forms of supposed perception outside (extra = outside) the senses, it could be argued that an unknown sensory capability could contribute, at least partly, to obtaining a partial cognition of either what someone else is thinking (telepathy) or some physical circumstance (clairvoyance). In this case the telepathy or clairvoyance would be forms of sensory and not extrasensory perception. The application of this less rigorous view of ESP is not consistent with the third capability, namely precognition. Precognition includes cognition of future events or circumstances for which no sensory stimulation of any type is (by definition) available. Those events or circumstances that are

predictable by existing scientific laws or knowledge are typically excluded from being considered under the category precognition (for example, predicting that someone falling from a second-floor window onto the ground may experience pain would be excluded).

The occurrence of paranormal events, including ESP, psychokinesis, and communicating with the dead in a form of posthumous telepathy or thought-transference, which was a major concern of the spiritualism movement and of the British Society for Psychical Research (SPR) founded in London in 1882 (Berloff, 1977), has been investigated by one or more of the following methods:

1. Historical analysis of events or predictions made long before the time of the analysis (e.g., predictions of Nostradamus).
2. Active investigation by a team of individuals (some believers, some not) from a group experienced in such investigations (e.g., the SPR or its 1862 predecessor, the Ghost Club of England).
3. A laboratory study in which possible factors that could contribute to the occurrence of an unusual event are appropriately controlled.

The first two of these methods are examples of post hoc (retrospective) investigations and are subject to the limitations present in such approaches. These limitations include (but are not limited to) inaccuracies in recall of events at a later date, recording errors, influence of uncontrolled but correlated stimuli (confounding variables, known and unknown), selective recall of data (including the file-drawer problem), non-random presentation of stimuli (with consequent attenuation of task difficulty), and chance. For laboratory (prospective) studies there are the same limitations (but more easily controlled) plus some additional limitations or problems (that may, also, be present with retrospective studies). These include problems of sensory leakage that can occur in unexpected ways. Some of the early ESP cards (Zener cards) used by Rhine were sufficiently translucent enough such that they could be apparently read from either side (Zener card, n.d.). Kennedy (1939) describes many possible sensory contaminants, including involuntary kinesthetic cues (e.g., Clever Hans), tactual cues, visual cues (playing card faces could be read when dealt over a polished table surface), and auditory cues (involuntary and, also, intentional in the form of a subject whispering in one study not noticed by the experimenter). Coover (1917) investigated corneal reflection, which could be an additional visual cue for those (sender and receiver) seated across a table from each other. Another contributor to sensory leakage comes from cases of anomalous perception in which an individual may have altered sensitivity permitting detection of

signals not perceived by the experimenter. For example one of the plates in the set of Ishihara pseudo-isochromatic plates used to test color blindness includes a target easily seen by certain dichromats but unseen by normal trichromats. Additionally, older experimenters with presbycusis may completely miss acoustic signals easily heard by young subjects (at least those who have not attended many rock concerts). Taste and odor blindness provide additional examples of this. Idiosyncrasies of perception may provide unexpected sensory cues not controlled by the investigator.

Rhine (1977) historically divides the period of psychical investigations into four 25-year periods from 1876 through 1975. The second period (1901–1925) included the early rise of experimental and statistical methods with varying results (some positive, some negative) from the contributions of Coover (Stanford), Troland (Harvard), Estabrooks (Harvard), McDougall (Harvard), and Brugmans (Groningen). Rhine devotes much of the third period (1926–1950) to a description of events in his laboratory at Duke University. A summary treatment of the earlier experimental work is given by Pratt, Rhine, Smith, Stuart, and Greenwood (1940) and Rhine and Pratt (1957).

Although the shift from retrospective to prospective (including laboratory experiments with objective stimuli and results) illustrates a shift to more rigorous findings, there remain many of the limitations already described plus some more yet to be considered. The presence of minor involuntary actions, weak or below threshold signals (i.e., detectable but unconscious), recording errors, shifting target criteria, selection of “good” data for retention and analysis, among other seemingly minor factors, may not appear to contribute that much to an artificially inflated result. When averaged over thousands of trials, apparently trivial results may, when statistically analyzed, reveal a highly statistically significant finding to which many will direct their attention.

Unfortunately, the existence of fraudulent findings has plagued paranormal investigations (as well as those in other fields). For serious researchers this is a source of embarrassment, particularly prevalent because of the questionable competence of many people who report paranormal findings. For example, with regard to the attempted assassination of Ronald Reagan, the news organization UPI on 2 April 1981 reported the following report of a taped interview (in part):

A psychic apparently predicted the Reagan assassination attempt during a television interview two months ago, accurately describing his assailant

and some details of the attack. Terry Rand, in a Jan. 6 appearance on Cable News Networks' Dick Maurice Show, said Reagan would have a "down cycle" in late March and early April and July. "I feel the chest areas ... a thud," she said in the interview, which was rebroadcast Wednesday on CNN. It "might imply some sort of heart attack. In my mind I can see a little scenario ... had to do with a gun ... shots all over the place. ..."

The next day UPI reported (in part): "Members of the crew of KTNV in Las Vegas who taped Miss Rand's interview which was picked up nationally by NBC, ABC, and Cable News Network on Thursday, said the tape was actually made last Tuesday, the day after the shooting, and not Jan. 6 as was reported when it was broadcast."

In this case the fraud was evident and discovered. In others one is left with the question of what really happened, which must be answered in order to assign significance to it. In science, generally, this is a transient problem because it is customary to require independent confirmation of findings by separate laboratories. As Murphy (1958) states, this is not the case with paranormal phenomena.

In-Class Experiment

In order to minimize or eliminate as many of these errors as possible so that a more meaningful test of ESP can be accomplished, the present empirical investigation of precognition was conducted. This type of ESP, when studied alone, would seem to avoid the sensory leakage present with investigations of telepathy and clairvoyance. The possibility of inadvertent control or bias by the experimenter (through non-randomization) necessitates a random set of stimuli that is new and unpublished (Bridgman, 1956), since published random digit tables could permit predictions based on knowledge of the table (clairvoyant or otherwise). Extreme rigor is required because, given the scientifically dubious status of ESP and other paranormal phenomena, one is reminded of the popularization of the Pierre-Simon, marquis de LaPlace expression given by Carl Sagan: "Extraordinary claims require extraordinary evidence" (Carl_Sagan, n.d.).

What follows is a description and cumulative results of this empirical investigation of precognition, conducted by me and done as an in-class instructional experiment after my series of lectures on the senses. The experiment was used not only to illustrate statistical and probabilistic interpretation but also to demonstrate the importance of using rigorous experimental design when studying perceptual phenomena.

Method

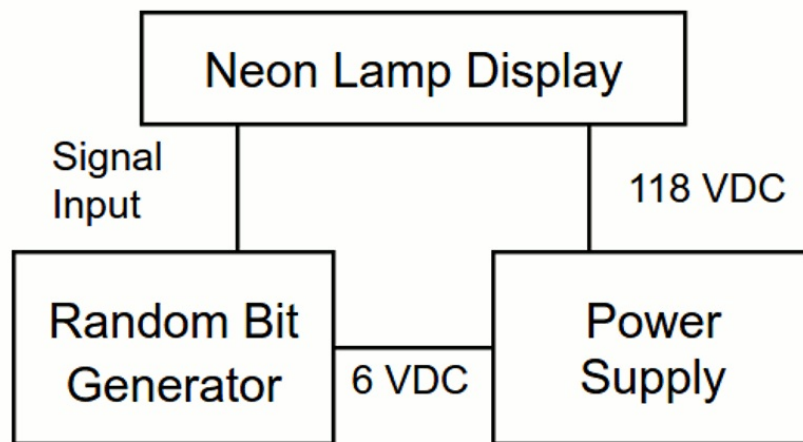
Subjects/Participants

A total of 4676 students enrolled in the author's General Psychology course from Spring, 1973 through Spring, 2010 (183 classes) and who elected to participate during a classroom lecture demonstration of an ESP experiment and statistical methodology served as subjects. Since no institutional review board (IRB) existed at the start of the experimental series and the primary purpose for the series was for educational instruction for all 183 classes, retrospective IRB authorization and approval was obtained for the project.

Apparatus

A random bit generator designed by the author was used to provide a random output that caused one or the other of two NE-2H neon lamps to turn on randomly while the other lamp remained off for each trial of a succession of 100 trials. Each randomized trial consisted of the experimenter pressing a normally open momentary button switch for approximately one second, after which (upon release) one lamp turned on and the other remained off. Randomicity was provided by the internal circuitry of the random bit generator along with the variability of time used when pressing the button. Specifically, the amplified output of a unijunction transistor relaxation oscillator having a frequency (measured with a frequency counter) of 93.8 kHz was used to drive the input of a bistable (J-K flip-flop) multivibrator whose outputs (Q and not-Q) at one-half the input frequency drove the inputs of two neon lamp transistor drivers such that the neon lamps would successively and exclusively alternate at a frequency of 46.9 kHz. A separate SPST switch provided the experimenter with the option of turning off the lamps during the toggling of the multivibrator until the button was released on each trial, at which time one lamp turned on while the other remained off. A single voltage-regulated power supply delivering separate 6 VDC and 118 VDC was used to power the random bit generator and the neon lamp module, respectively. The random bit generator, neon lamp display (with right- and left-positioned lamps, designated R and L below), and power supply were interconnected modular units designed and constructed by the author. The original frequency counter was also designed and constructed by the author, although later measures were done with a commercial B&K Precision Model 1822 frequency counter. **Figure 5.1** shows a block diagram of the approximate arrangement of the devices as seen by students in the classroom. **Figure A1** in Appendix A shows a photograph of the three interconnected modular units as setup in a classroom used for many of the experimental

sessions. Circuit descriptions, including a diagram of the random bit generator, are also provided in Appendix A.



[[Figure 5.1](#)] *Interconnected Arrangement of Electronic Devices Used for ESP Experiment*

Prior to conducting the first experimental session, the random bit generator was partially tested for randomness by automatically (with an RC-controlled timing circuit) generating ten sets of 10000 trials/set with the inherent jitter of the timing circuit providing the intended randomness. Electrical counters were used to separately record the cumulative number of left- and right-lamp outputs. When the combined total reached 10000, the set was stopped, and the numbers of lefts and rights were recorded. The next set was, then, begun for the next 10000 trials. **Table 5.1** lists the results of this apparatus test.

Date of Test	Left Lamp Count	Right Lamp Count	Chi-Square	P
1 Feb. 1973	4982	5018	0.1296	0.72
1 Feb. 1973	4961	5039	0.6084	0.44
2 Feb. 1973	4944	5056	1.2544	0.26
3 Feb. 1973	5020	4980	0.1600	0.69
3 Feb. 1973	5070	4930	1.9600	0.16
4 Feb. 1973	4913	5087	3.0276	0.08
5 Feb. 1973	5058	4942	1.3456	0.25
5 Feb. 1973	4918	5082	2.6896	0.10
6 Feb. 1973	4978	5022	0.1936	0.66
7 Feb. 1973	4965	5035	0.4900	0.48
Total	49809	50191	1.45924	0.23
Note: Theoretical binomial 95% CI = 5000 ± 98 (4902 - 5098) for 10000 trials. Theoretical binomial 95% CI = 50000 ± 310 (46690 - 50310) for 100000 trials. (Normal approximation to the theoretical binomial distribution for both CIs.)				

[Table 5.1] *Partial Test of the Randomicity of the Random Bit Generator*

Procedure

For each of the 183 sessions, the same procedure (with an exception as described below) was followed. As part of the course immediately following coverage of the senses, the topic of hypothesized paranormal phenomena was introduced in lecture. After briefly describing some major categories of paranormal phenomena (extrasensory perception, including telepathy, clairvoyance, precognition, and psychokinesis), the instructor invited students in the room to voluntarily participate in an experiment investigating the ability to predict accurately which of two neon lamps would turn on during each of 100 trials. As an inducement to participate, the instructor announced that in the unlikely event that anyone would score 90 or more correct, a total (to be divided by all who so scored) of \$100 would be given to that (those) person(s) who did so. The exception, mentioned above, is that this monetary award was made for all classes from fall, 1973 through spring, 2010 (N = 4581) but not to those in classes from spring, 1973 through summer, 1973 (N = 95). Immediately after this announcement, two identical prediction sheets, each containing a matrix of rows of numbers adjacent to the letters L and R (e.g., 89 L R) with the numbers ranging successively from 1 through 100, were given to each student in the class. The instructor then asked those who wished to participate to mark through either the L or R (but not both) that the participant predicted would correspond to the neon lamp turning on for each of the 100 trials. After making predictions, they were to transcribe their predictions to the second sheet, thus making two identical sets of predictions. One sheet was turned in with their name included (serving as the official record of their predictions). The second sheet was retained for student self-scoring when the master key sequence of right and left alternatives was being generated later in that class session.

The master key sequence was then generated by the experimenter who pressed the button on the random bit generator for approximately one second, noted which lamp was on following release, vocally announced that result ("Left" or "Right") to the class, and recorded the result by marking through that location (either L or R) with a felt-tip pen on a master key sheet (an unused prediction sheet) before going to the next of the 100 trials. Self-scoring by students was done by marking through those trial numbers on their retained copy of the predictions for which their prediction was incorrect. After trial 100 a separate student self-scored data sheet was then passed around for participants to record their name and score. At this point during the class session, students were asked how many made a score above 89, how

many scored above 70, how many scored above 60 or below 40, and how many scored within the closed interval 45-55. Their responses were immediately compared to predictions based on an exact binomial model. Following the class session, the prediction sheets that served as the official records of students' predictions were regraded independently and compared with those reported on the self-scored data sheet. When the independent scoring revealed the same score as that reported by the participant, that was the score determined for that record. For those which differed, the prediction sheet was re-scored repeatedly until two score determinations agreed; the agreed score was determined to be the score for that record.

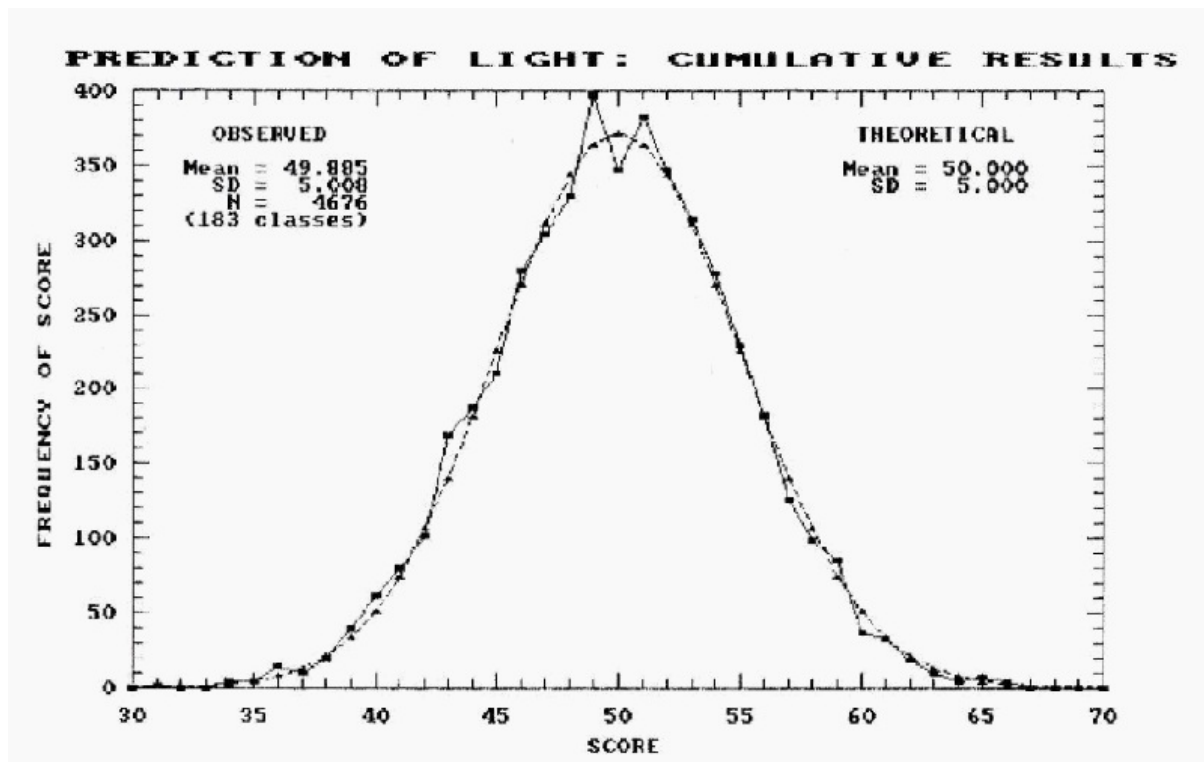
Following the independent scoring, the scores for that session were tabulated with regard to frequency for each score (from 0-100), mean score, standard deviation (SD), number of participants, sum of scores, and sum of squared scores. Additionally, the cumulative number of scores, mean, SD, sum of scores, and sum of squared scores were recorded for each successive session. Also, for each session, the frequency of each score was recorded and, then, separately added to the score frequencies of previous sessions to provide a cumulative distribution of score frequencies.

Results

Cumulative results were determined for the 4676 participants across 183 experimental sessions. A discrepancy was found between the total number indicated by the cumulative distribution of score frequencies ($N = 4718$) and the separate number used for cumulative calculation of means and SDs ($N = 4676$). Because the cumulative determinations of means and SDs were done by calculator and the cumulative distribution of score frequencies was done usually without a calculator (because of the small integer values involved), it seems likely that some errors may have occurred and increased through accumulation of the non-calculator-based values. The calculator-determined values are regarded as more likely to be accurate and, consequently, are given below (with the other values based on score frequencies given in parentheses).

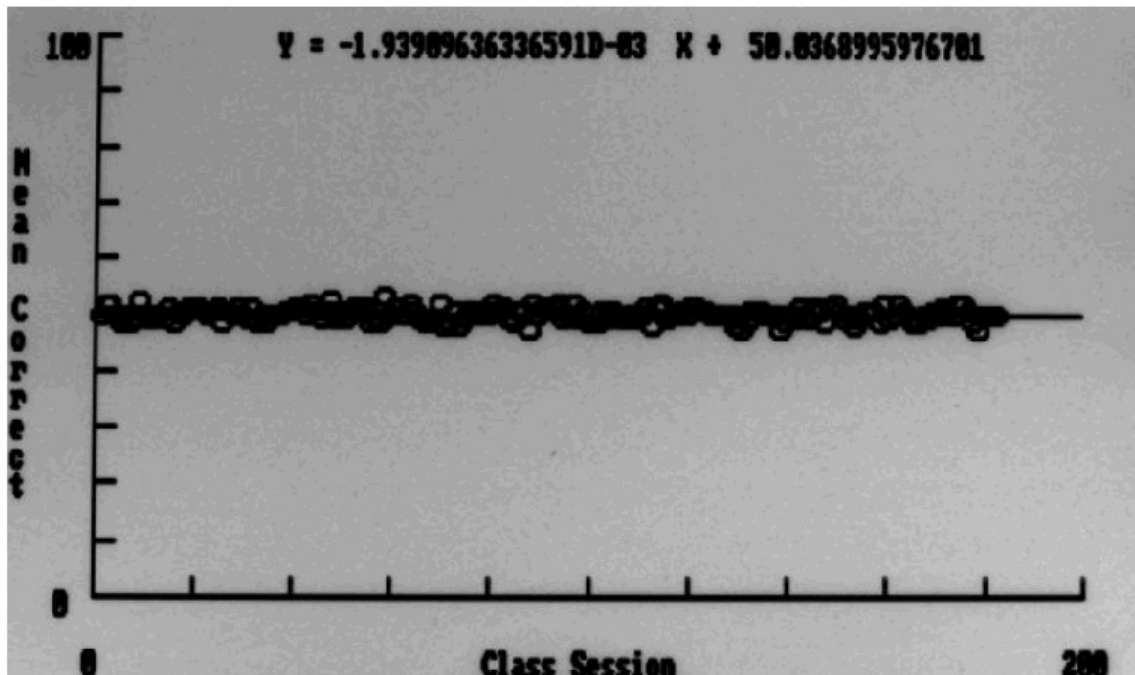
The mean score obtained was 49.885 (49.871) with a standard deviation of 5.008 (5.006) for all 4676 (4718) participants in the 183 successive classes. The lowest score was 31 and the highest score was 66. These results are graphically illustrated in **Figure 5.2**, which shows the obtained calculator-based frequency as a function of score (based on 4676 participants) and a smooth theoretical curve based on the exact binomial distribution (not the normal approximation) for $N = 4676$. In either case (calculator-based or not),

the theoretical mean falls within the 95% confidence interval of the observed mean.



[[Figure 5.2](#)] *Obtained and Theoretical Scores for Predicting which of Two Lamps will turn on for each of 100 Trials. Data were collected from Spring, 1973 through Spring, 2010.*

Additionally, **Figure 5.3** shows a plot of session mean scores across 183 class sessions in which the number contributing to each mean varies from session to session.



[Figure 5.3] A Plot of Mean Scores across Class Sessions (of Variable Sizes). The least-squares regression equation $Y = -0.001939 X + 50.04$ (rounded) describes the line descriptively fitting 183 equally-weighted points.

Discussion

Recognizing that some errors have occurred over the 183 experimental sessions, as will unfortunately happen (Kennedy, 1939), it appears, nevertheless, that by using either set of results, means and SDs are consistent with the view that chance, alone, may account for the results. Although the values of obtained mean and SD based on $N = 4676$ are included in Figure 5.2, the data points correspond to the larger $N = 4718$, so that all subjects who provided voluntary, readable, and valid responses (i.e., unambiguous responses of either L or R to each of 100 trials) are included in the graph. An incidental observation made when independently grading the response sheets was that self-graded scores were in error typically 25 to 40 percent of the time, varying from session to session.

The initial purpose of this series of experimental sessions was to provide what was hoped to be an interesting epilogue to the typical coverage of sensation and perception in a format that would also illustrate experimental procedures and statistical considerations. Consequently, the experimental program was designed from the start to be rigorous to the degree that it might be of publishable quality, whichever way the results indicated. The demonstration experiment would need to be done with a time constraint (limited to one class

period, at most), be done in a public manner with clear and unambiguous stimuli, and provide educational feedback to the class. A precognition task was selected in order to reduce or eliminate the possibility of sensory leakage. Psychic leakage could still theoretically occur through psychokinesis determining some or many of the individual trial results, hence the use of "reduce" in the previous sentence. The task was selected to be an unequivocal and clearly statistically treatable procedure as opposed to some of the more complex procedures that are difficult to analyze (Diaconis, 1978). For illustrations of these complex procedures, see Wolstenholme and Millar (1956) and Schmeidler and McConnell (1958).

In order to avoid unintentional bias in generating unpredictable stimulus sequences, a randomizing procedure was needed that would be obvious to the class and would be preferably random. This excludes simple coin flipping (Coin_flipping, n.d.; Coin Tossing, n.d.), which is not completely random, and trials based on pseudorandom numbers as generated by the popular and easily programmed but completely deterministic mathematical method of linear congruence, which makes its use in cryptography of no value because of its predictability (Schneier, 1996). Although some true randomization procedures are available (based, for example, on radioactive decay, Schottky noise, Zener avalanche breakdown, etc.), the more convenient procedure involving varying time intervals as described here was decided upon.

Although the results fail to indicate a need to suppose anything other than chance is operating, some components of the experiment provide information concerning the third question mentioned in the introductory section of this chapter:

What exactly signifies a paranormal occurrence?

If what signifies a paranormal occurrence is not clearly indicated before an experiment on the topic is conducted, answers to this question can be deceptively misleading. For example, the criteria for a correct response (i.e. what indicates a paranormal occurrence) could be retrospectively modified through selection of favorable data after the experimental session (Kennedy, 1939). A related version of this error is known as the Texas sharpshooter fallacy in which the target is drawn after the shooting (Texas sharpshooter fallacy, n.d.). Although not an experiment, consider a case in which Jill has a romantic interest in Jack and concludes that Jack's gazing at her to be a manifestation of reciprocated romantic interest. Alternatively, if Jack is not gazing at Jill, Jill considers Jack as not wanting to be obvious in his romantic interest of her. Here we have two different responses (Jack's gazing or not

gazing at Jill), either of which leads to the same conclusion by Jill: Jack has a romantic interest in her. Although possibly unintentional, Jill has clearly “stacked the deck” in favor of concluding what she desires to be true (for Jack to be romantically interested in her). In experiments, unintentionally “stacking the deck” to get favorable results must be ruled out by rigorous experimental design.

More frequently, however, some event happens that seems unusual to the extent that its rarity indicates something of a paranormal kind has occurred. An example of this is a so-called miraculous cure in which there is a complete remission of symptoms for unknown reasons. Alternatively, consider the report given in a *U.S. News & World Report* in 2011 and summarized by Hand (2014, p. 12) as follows:

It refers to the late Kim Jong-Il, former leader of North Korea, and says “In 1994 the very first time he played golf, Kim Jong-Il dominated the 7,700-yard Pyongyang Golf Course. He shot an unimaginable 38-under par, recording no less than a birdie at the country’s lone golf course. His round included 11 holes-in-one, and the feat was verified by 17 bodyguards who were present.”

Such an unprecedented display of golf-playing prowess indicates either extremely rare events have occurred or some errors have been incorporated into the report, which would modify its significance. In either case, the report likely attracted attention.

In August, 2016, a report by ESPN (among others) described this instance of an unusual happening (ESPN, 2016):

You can’t make this up! Brandon Thomas hit a grand slam deep over the left field wall tonight. He smashed a windshield in the parking lot! Only one problem. That’s his own truck!

Some events are sufficiently public and rigorously established to be considered as valid rare events. Included among these are some astronomical phenomena such as the transit of Venus (Transit of Venus, 2012) and the collision with Jupiter by the Shoemaker-Levy 9 comet (Shoemaker-Levy 9, n.d.). Both of these events were predicted to occur and publicly observed. These events differ in that the transit of Venus is a recurring event, whereas the collision with Jupiter is unique and was made visible by modern technology. Both are, nevertheless, rare in human experience, and they happened and were noticed by many people and recording instruments. The objective recording reduces the likelihood of an erroneous report. We may,

thus, conclude that (in each case) a rare event has occurred.

We cannot, however, specify the probability that a rare event such as the Shoemaker-Levy comet collision would occur. The collision only seemed to be highly unusual and improbable (based on the history of similar occurrences) and, as a result, garnered significant attention. Other highly unusual and improbable events occur on a daily basis in our lives but are not recognized as such and, as a consequence, do not attract our attention.

By way of contrast, consider one of the sample keys used in this in-class experiment and illustrated in **Figure 5.4**. As will be described, this provides an example of an unusual event which can, also, be quantifiably evaluated in its probability of occurrence.

INSTRUCTIONS: Mark through the letter corresponding to the light for each trial that you think will light; L if the light on the left and R if the light on the right.

TRIAL	TRIAL	TRIAL	TRIAL
1 ☒ R	26 ☒ L ☒	51 ☒ L ☒	76 ☒ R
2 ☒ L ☒	27 ☒ R	52 ☒ R	77 ☒ R
3 ☒ L ☒	28 ☒ R	53 ☒ R	78 ☒ L ☒
4 ☒ L ☒	29 ☒ L ☒	54 ☒ L ☒	79 ☒ R
5 ☒ L ☒	30 ☒ R	55 ☒ L ☒	80 ☒ R
6 ☒ L ☒	31 ☒ L ☒	56 ☒ R	81 ☒ R
7 ☒ R	32 ☒ R	57 ☒ L ☒	82 ☒ R
8 ☒ L ☒	33 ☒ R	58 ☒ L ☒	83 ☒ L ☒
9 ☒ R	34 ☒ R	59 ☒ L ☒	84 ☒ L ☒
10 ☒ L ☒	35 ☒ L ☒	60 ☒ R	85 ☒ R
11 ☒ R	36 ☒ L ☒	61 ☒ L ☒	86 ☒ R
12 ☒ R	37 ☒ L ☒	62 ☒ L ☒	87 ☒ L ☒
13 ☒ L ☒	38 ☒ L ☒	63 ☒ R	88 ☒ R
14 ☒ R	39 ☒ L ☒	64 ☒ L ☒	89 ☒ R
15 ☒ L ☒	40 ☒ R	65 ☒ L ☒	90 ☒ R
16 ☒ L ☒	41 ☒ R	66 ☒ L ☒	91 ☒ R
17 ☒ L ☒	42 ☒ R	67 ☒ L ☒	92 ☒ R
18 ☒ L ☒	43 ☒ R	68 ☒ L ☒	93 ☒ L ☒
19 ☒ R	44 ☒ R	69 ☒ R	94 ☒ R
20 ☒ R	45 ☒ R	70 ☒ L ☒	95 ☒ L ☒
21 ☒ L ☒	46 ☒ R	71 ☒ R	96 ☒ L ☒
22 ☒ R	47 ☒ L ☒	72 ☒ L ☒	97 ☒ R
23 ☒ R	48 ☒ R	73 ☒ L ☒	98 ☒ L ☒
24 ☒ L ☒	49 ☒ L ☒	74 ☒ R	99 ☒ R
25 ☒ R	50 ☒ R	75 ☒ L ☒	100 ☒ R

[[Figure 5.4](#)] *Sample Key*. This key was generated during the Spring, 2010

session.

This brings me back to the third question asked in the introductory section of this chapter: What exactly signifies a paranormal occurrence? Generally, events perceived as being paranormal are rare and noticed (as alluded to previously), but might there be other events that are, also, rare and not noticed? Consider the session key illustrated in **Figure 5.4**. This is the actual key for session 183 that resulted from 100 random binary choices generated as described in the procedure section and is similar in format to the other 182 previously generated session keys. This collection of choices happened. Suppose we raise the question: What is the probability of getting this particular sequence? Since the trials are independent, the sequence probability is the product of the separate trial probabilities. This results (after some math) in one chance in 1,267,650,600,228,229,401,496,703,205,376 (or, when rounded, 1.2676506×10^{30}). The probability of this event (or any other sequence, such as 100 Lefts) is the reciprocal of this number. In order to provide some perspective on this, let us consider that a hypothetical ultra-ancient and very energetic individual began conducting trials of this sort at a rapid rate, namely, 1,000,000 sequences/second of 100 trials in each sequence from the start of the known Universe (coincident with the Big Bang), estimated to be about 13.8 thousand million years ago (with apologies to Bishop Ussher). Given that one solar year is 31,556,925.51 seconds, this makes the age of the Universe to be approximately 4.3548557×10^{17} seconds old. (The results based on sidereal years are slightly different, but similar.) The overall consequence of this is that the sequence given in **Figure 5.4** is an event that is expected to happen (at a rate of 1,000,000 sequences/second) about once every 2,910,890 ages of the Universe. But it happened.

By now you may be thinking of the other 182 sessions and their likelihood of occurrence. Since each of the sessions was independent of other sessions in the determination of the resulting key of 100 random lefts and rights, the chance of getting the particular sequence of lefts and rights in a total of $183 \times 100 = 18300$ individual trials is one chance in (rounded)

$$7.06188516 \times 10^{5508}$$

which, when converted at a rate of 1,000,000 sequences/second, is a duration of

$$1.6216117 \times 10^{5485}$$

(a little more than 16 followed by 5484 zeros) ages of the Universe (a long

time).

When one attempts, retrospectively, to evaluate the probability of occurrence of some apparently rare event in history, the evaluation is not usually based on simple statistically independent binary trials permitting clear assessments of probability. Instead, we have compound probabilities based on mutually non-exclusive events (some known and others unknown) making the determination of objective (as opposed to subjective) probability difficult.

Consider the rhetorical comment made by the physicist Richard Feynman in a lecture: “I had the most remarkable experience this evening. While coming in here I saw license plate ANZ912. Calculate for me, please, the odds that of all the license plates in the state of Washington I should happen to see ANZ912” (Feynman, 1998). The probability, if computed, would depend upon the joint probabilities of Feynman being there, his witnessing the license plate, his being invited to talk, his educational background, his being born in the twentieth century, his parents meeting each other, and a large number of hereditary factors jointly occurring. As one might speculate, there are many other factors not mentioned that would have to be additionally satisfied in order for this observation to have been made.

Events in life occur and, when retrospectively analyzed, subsequently appear improbable to the point of seeming impossible. Each semester when I presented the ESP precognition task in class, I indicated the unnoticed but, nevertheless, rarity of the results illustrated by the key in **Figure 5.4**. Until I calculated the results for 183 independent keys, in addition to those for a single key, I was, myself, unaware that an event occurring during one class session, with a consequent key being generated that would happen (at a rate of 1,000,000 key sequences/sec) about once every 2.9 million ages of the Universe, is (relatively speaking) a daily event. It appears that in the grand universal sequence of events, the occurrence of any specific event is virtually impossible. This book may not exist, since it is dependent upon the 183 separate sets of results, thus providing an upper bound in probability to be less than $2^{(-18300)}$, which is not far from zero.

Summary

In this chapter I have described and illustrated an alternative view of perceptual and attentional reality in which some forms of perceptual input are believed to occur outside the mechanism of the senses. Although popular descriptions of extrasensory perception (ESP) frequently describe this capability as another sensory input, yet to be discovered, it is (as the

etymology of the name indicates) a kind of perceptual input that occurs without involving any sense, known or unknown. It is truly an extrasensory (extra = outside) phenomenon. The question remains as to whether or not it occurs. The first part of the chapter described historical approaches to investigating it in its various possible manifestations and some of the problems encountered in establishing the validity of ESP. The second part of this chapter describes an experiment into the phenomenon of precognition, one form of ESP, which I initially conducted in 1973 and replicated 182 times over the years since then. Results of this experiment were cumulatively combined into a composite result based on the 183 experimental sessions. Although no evidence of precognition was found, it was noted at the end of the chapter that several very rare and unusual events did occur, even though, unless pointed out, they might have escaped notice. These unusual events consisted of, for each experimental session, the sequence of 100 instances of either the right light or the left light turning on, and, for all experimental sessions, the resulting sequence of 18,300 instances of either the right light or the left light turning on. Whether 100 or 18,300 random events, the overall probabilities are, in each case, extremely low and involve considerations to which I will return in Chapter 6.

Chapter 6 – Evaluation of Anomalous Events

Rare Events

Although the precognitive experiment (described in Chapter 5) in its replications failed to reveal any evidence for the occurrence of ESP as an extraordinary phenomenon, my analysis of the implications of each set of 100 trials (per experimental session) indicates that very rare events occur frequently and regularly. Take, for example, the Spring, 2010 session key (**Figure 5.4**) as illustrated in Chapter 5. Each trial in the set of 100 trials was determined by which of either one or the other of two lights turned on randomly as determined by the output of a random bit generator. What is the probability of getting such a key? The probability of whether a particular light will randomly turn on or off for each trial is the same probability one would get by flipping an unbiased coin and getting either heads or tails. In this case, one light would represent heads and the other would represent tails. Continuing with this analogy, if one were to flip an unbiased coin at a rate of 1,000,000 sets per second with each set consisting of 100 successive flips, a particular set would occur, on average, once each 2.9 million times the age of the Universe. This may be a consequence of the law of inevitability, which is described by Hand (2014) as a “simple fact that *something must happen*.” It is not that rare events occasionally, rarely, or never occur; it is, instead, that they occur all the time. We just notice some of them and not others. Why should this be so?

Chunking and Awareness

Consider the following two strings:

String A: T H H T H T H H T T

String B: H H H H H H H H H H

String A was obtained by flipping a coin ten times, and the result might be considered to be random (but see Coin flipping, n.d.; Coin Tossing, n.d.). String B might have been obtained by flipping a coin ten times—but was not (I confess). Nevertheless, both strings are possible outcomes of a randomized set of ten trials of coin flipping, and both are equally probable. When viewed, however, String B is likely to be much more easily remembered (and noticed) than String A. String B can obviously be more easily chunked (see chunking as described in Chapter 3) and reduced to a smaller memory load than String

A.

The sequence of events one encounters in everyday life may, occasionally, be similar to String B and be easily noticed and recalled. The probability of such a string of events, provided that the probability for each event can be independently specified (as in the case of coin flips) and the events are independent, can be determined and evaluated. In the case of less easily remembered and noticed strings, such as String A, where the probability of each item can be identified and the items are independent (as I illustrated with the 100 trials of either the left or right lamp turning on), the string sequences may be less noticed unless recorded (and subsequently analyzed).

In everyday life we encounter what may be interpreted as longer strings, which I will refer to as String C. String C includes individual items of unspecified probability that are likely to be of different probabilities across the elements of the string. The individual components of String C may or may not be independent (or have unknown independence). They are, therefore, difficult to remember or chunk and impossible to precisely evaluate in terms of probability of occurrence. About all that can be said is that they (the components of String C) seem to be highly unlikely. That they occur would be an instance of Hand's law of inevitability operating. Hand (2014) describes this law (among others) in his book in terms of easily describable examples, such as rare outcomes of games of chance, winning a lottery, or quirky historical accidents. As Hand describes the improbability principle, it "*asserts that extremely improbable events are commonplace.*" This may be seen more clearly through the following hypothetical event:

Imagine that you are visiting another country. Consider this other country to be England. During your visit, as part of String C, you encounter a familiar person standing in line, immediately behind a Korean visitor, a person whom you know from home. Quickly doing a subjective calculation based on the estimated world's population, you conclude that this encounter is an extremely rare event to have happened by chance. It is, indeed, true that this is a rare event and one noticed by you. What seems to be not noticed is the equally rare event of the Korean visitor (and, for that matter, everyone else you encounter that day). As Hand states, extremely improbable events are commonplace. I would add that they are usually not noticed. Why should such events occur?

Predestination

By predestination I mean a temporal arrangement in which knowledge of

what will happen at Time2 is known accurately at Time1, where Time1 is less in absolute age than (that is, occurs before) Time2. The difference in time between Time1 and Time2 may be of the magnitude of minutes, days, or years. Customarily, the *deus ex machina* for the operation of knowing what will happen in Time2 at Time1 is a deity. This is illustrated by the, theologically interpreted to be omniscient, God of Christianity as emphasized by John Calvin, among many others within and outside Christianity. Theologically, this usually involves disputes between such factions as the supralapsarian and infralapsarian groups involving their interpretations of just when God chose his elect (i.e., before or after the Fall, respectively). Much unverifiable (as far as I know) commentary has been written about these concerns over the years, and I will not continue the theological discussion here. Instead, I will simply say that the idea of predestination, whether from one or more deities or some other origin (such as Laplace's demon), implies that certain informational things are known before their occurrence. This is the underlying principle, theologically based or not, for the theoretical validity of precognition (investigated in the experiment described in Chapter 5).

Prophecies and Predictions

If one has knowledgeable access to the thoughts that whatever omniscient gods may have, then accurate predictions (or prophecies) about future events may be made. If these predictions are accurate, then they would be consistent with the view that the prophet (or predictor) has access to the knowledge of the gods. They are, also, consistent with the possibility that the predictions are fortuitously (albeit improbably) correct. A major concern for such predictions to be taken seriously is that the prediction or predictions be unambiguously made, since ambiguity of prediction has been a noted problem. This ambiguity has already (in Chapter 5) been noted with respect to some of the forms of extrasensory perception and is also evident in the prophecies of Nostradamus. Similarly, Pythia, the priestess serving as the incumbent oracle of Delphi, was known to give highly ambiguous answers to questions provided by persons making significant life decisions. For example, when Croesus (King of Lydia) asked about whether he should wage war against the Persians, she reportedly replied that, if done, a great military force would be defeated. He did so, and *his* army was defeated.

It will, I think, be readily agreed that some events can be highly and accurately predicted. The movements of celestial objects can be accurately specified for the future (and postdicted for the past). There are events of considerable importance to many people involving behavior of other humans,

such as the driving behavior of other drivers on the road. We make life-or-death predictions of their future behavior as we approach them. When their behavior becomes less predictable (e.g., because of elevated blood alcohol levels or use of a cell phone while driving), our concern for the accuracy of our predictions increases.

The Explosive Universe

By explosive I mean not only the Big Bang but also the explosion of knowledge that has occurred over the centuries about the extent of the Universe. This includes the Babylonian/Hebrew concept of “universal reality” consisting of a flat disc-shaped earth situated below a bowl-shaped firmament in which are embedded the sun, stars, planets, and moon. Directly above the earth (and below the firmament) is the cloud-containing atmosphere. Above the firmament is a large expanse of water. Located beneath the flat disc-shaped earth is a subterranean Deep, containing yet more water and a somewhat ambiguously defined region called Sheol serving as a repository (in some fashion) of the souls of those who have died. This interpretation of reality might seem to be very plausible to one who simply observes what seems to happen while reclining and looking up (as day changes to night). After all, there was not TV or Internet at this time and no way to precisely determine stellar distances. Paralleling this view, which seems to have prevailed until two or three centuries BCE, at this time were initial speculations by some Greek philosophers, astronomers, and others about a spherical earth and celestial sphere. Although Aristarchus, a Greek philosopher of the third century BCE, suggested a heliocentric (sun-centered) view of the “Universe” (as known then), the geocentric view advanced by Ptolemy (ca. 150 CE) became the dominant view for more than a thousand years (Scharf, 2014). Various authors have indicated that the Ptolemaic theory achieved its prominence possibly as a consequence of its incorporation into Christian views of the Universe. The posthumously published view of the solar system (and stars) with the sun as the approximate center (hence heliocentric theory) by Nicolaus Copernicus midway into the 15th century CE revolutionized the views of cosmology, although (as he recognized) there remained technical problems with it (Scharf, 2014).

Based on meticulously recorded observational data (at this time without telescopes) provided by Giordano Bruno and Tycho Brahe (both of whom experienced untimely deaths, theologically induced for Bruno and an apparent health problem for Brahe), Johannes Kepler determined that planets moved in elliptical—not perfectly circular—orbits around the sun (Scharf, 2014). By

using a telescope built after the design of Hans Lippershey (Angelo, 2006, p. 372), Galileo viewed and discovered the four "Galilean moons" of Jupiter, sunspots, and phases of Venus. He began a revolution, made possible by the telescope, in observational astronomy.

Stellar Parallax and Star Distances

The question of stellar distance became a continuing problem. Although the geometric concept of parallax had been known for centuries, no apparent indication of parallax for any of the stars existed. Finally, with improved instrumentation, the astronomer Friedrich Bessel was the first to fairly accurately determine a distance for a star, 61 Cygni (Perryman, 2012; see, also, Abell, 1980, p. 346). Previous attempts to establish parallax distance determinations were unsuccessful because of difficulties in measuring the very small angles that needed to be accurately measured and have continued to be difficult because of measurement contamination by atmospheric turbulence. Other methods, such as apparent brightness (based on stars serving as "standard candles"), Cepheid variable stars, Type Ia supernovae, Herzprung-Russell spectral absolute magnitude estimates, and red shift estimates for extra-galactic light sources have provided us (over the years since) with an ever increasing awareness of the size of the known (visible) Universe as it now appears.

As we move from the Babylonian/Hebrew cosmology with its stars appearing an unspecified but evidently short distance away to the more expansive view provided by astronomical developments up to the beginning of the twentieth century, we find, nevertheless, a continuing spatially limited view of our Universe. Stars had, by this time, moved light years in distance from the locality suggested by the Babylonian/Hebrew cosmology to more remote locations based on the stellar distance measurements prior to 1900 CE.

Expanding Views of the Universe after 1900

As of the year 1900 CE, a small number of stars (compared to the number in the Milky Way) had their distance from the Sun established by parallax determinations. This number was limited because of the very small angles involved for other than the nearest stars. Weinberg (2008, p. 15) indicates that ground-based parallax determinations, because of atmospheric limitations, reveal distances out to approximately 30 parsecs (or slightly less than 100 light years). For those whose stellar distance had been determined, there was, nevertheless, clear evidence that the Universe extended beyond the solar system into the realm of the Milky Way, which was, as of this time, the

Universe. Unclear, however, were distances to a number of nebulous structures having the appearance of (for some) comets that did not move. The comet-hunter Charles Messier called these nebulae and constructed a catalog of them in order to distinguish these non-comets from newly viewed comet candidates (which were of primary interest to him). Initially, these nebulae were thought to be part of (contained within) the Milky Way galaxy. Stellar parallax was hopelessly inadequate and revealed nothing, although in 1900 CE the reason was unclear. The vastness of the Universe would not be indicated until revealed in the next 100 years of astronomical investigation. As of 1900 humanity's unique place in a Universe made for man remained plausible despite what some called the Copernican principle (Scharf, 2014). Although Henrietta Leavitt discovered a relationship between the maximum luminosity of Cepheid variable stars and the duration of their period of variation in luminosity in 1908 (Baker & Fredrick, 1971; Angelo, 2006), the utilization and significance of this finding did not become known for a few years thereafter. For example, in 1920 a major debate between Harlow Shapley and Heber Curtis over the intra-galactic or extra-galactic location of the Andromeda Nebula occurred with Shapley maintaining the intra-galactic view. Shapley did correctly locate our Sun "far from the center" of the galaxy (Perryman, 2012). A few years later Edwin Hubble measured Cepheid variable stars in the Andromeda Nebula and established that it was clearly extra-galactic (Perryman, 2012). Baker & Fredrick (1971, p. 392) provide a simple equation for determining stellar distances using Cepheid variables:

$$\text{Log}_{10} r = (m - M + 5)/5$$

where r is the distance in parsecs (1 parsec = 3.2616 light years; Weinberg, 2008), m is the apparent median magnitude of the star, and M is the absolute magnitude of the star (as determined from the duration of the period of luminous variation).

In addition to the distance estimates provided by Cepheid variable stars serving as a type of comparison candle, there are other methods that provide intermediate distances based on absolute magnitudes indicated by their dominant color temperature. Hertzsprung and Russell, early in the 20th century, cataloged stars on the basis of dominant color, which indicates age and absolute magnitude. By comparing the apparent with the calculated absolute magnitude of a given star, it is possible to estimate the distance based on the inverse-square law. Weinberg (2008, p. 20) illustrates the comparison of main-sequence ("main sequence photometry") evaluation of distance to the Pleiades, giving a distance of 132 parsecs (omitting error range). Parallax determination using satellite observation (which provides greater accuracy

than ground-based measures) indicated a distance of 118 parsecs based on the Hipparcos satellite and a value of 133 parsecs from the Hubble Space Telescope. Although there is disagreement between measurement results, the comparison illustrates the cosmic distance ladder approach using methods having overlapping ranges.

Another “standard candle” in the distance measuring toolbox is the Type Ia supernova, which can be seen at far greater distances because of its inherent (and rather uniform) luminosity across supernovae. Comparisons have been made with Cepheid variables (which are, themselves, very luminous) for a small number of calibration instances. They provide another “rung” on the cosmic distance ladder. (See Weinberg, 2008, for more details.) Large extragalactic distances ($> 1.5 \times 10^9$ light years) may be determined on the basis of redshift measures (Coyne, 2004).

Anthropic Principle

We exist. Why?

Consider the following timeline:

Past:

Big Bang

(13.7 or 13.8×10^9 years ago)

Present:

Now

Future:

Universal Heat Death

(At least 10^{100} years from now)

Theoretically, we could not have existed (as far as we know) prior to the Big Bang, and prospects for continued life after the hypothetical Universal Heat Death, because of the second law of thermodynamics, seem bleak. Since we exist, we do so presumably within the time window designated above as the Present (by which I mean all time since the Big Bang until the Universal Heat Death of the Universe). Because of the presumed impossibility of existing outside this time window, there are temporal and conditional constraints on our existence. Such a viewpoint might be termed a very weak anthropic principle. The idea of an “anthropic principle,” which is widely and variously defined (see Carter, 1973, and Barrow & Tipler, 1986), seems to have

emerged as a reaction to an over-emphasis on the Copernican principle in which humans are no longer viewed as being at the center of the Universe and have become increasingly insignificant as a result of increases in knowledge about the extent of the cosmos, particularly with regard to the extragalactic components (including several dozen galaxies in the Local Group and those galaxies beyond). The anthropic principle maintains that there are constraints to our existence. A very good and non-technical introduction to the anthropic principle is given in “Anthropic principle” (2016). In my very weak anthropic principle, described above, our existence is limited to the time window designated as “Present.” Without the Universe existing in the Present, we could not exist. This is, I think a simplified version of what is called the Weak Anthropic Principle. There are certain conditions that must be met in order for life, and humans in particular, to exist. Such existence requires the formation of stars permitting the nucleosynthesis of elements up to iron and including supernovae for the production and dispersion of heavy elements beyond iron (as well as of the lighter elements). In addition, planets of a certain size and distance from an associated star with available liquid water and the presence of chemical elements, e.g., carbon, are required for the development of and sustained existence of life as we know it. The Weak Anthropic Principle, described by Carter (1973) and others, describes this kind of conditional existence. Some, such as Barrow & Tipler (1986), have advocated a Strong Anthropic Principle based on an expanded set of circumstances, including dimensionless constants, believed to be uniquely required for life, that have been present on Earth for the last several thousand million years or in the Universe since the Big Bang. Sharpe & Walgate (2002) provide an excellent modern review of varied views of the anthropic principle.

Martin Rees (2000), England’s Astronomer Royal, has suggested in his book, *Just Six Numbers*, that six (critical) numbers, the exact values (with little permissible deviation) of which have jointly determined the existence of the Universe. He has suggested the following six numbers with each contributing necessarily to the existence of the observable Universe as we know it:

1. $N = 10^{36}$: (1 followed by 36 zeros) Identified as the ratio of the strength of electrical forces holding atoms together/force of gravity between them.
2. $\epsilon = 0.007$: This is the value for the atomic nuclei binding force. If it were 0.006 or 0.008, “we would not exist.”
3. Ω : Indicates the amount of material in the Universe and the “relative importance of gravity and expansion energy” in the Universe. Too high results in universal collapse and too low would have prevented galaxy formation.

4. λ : [frequently written as upper-case, Λ] Described as “a cosmic ‘antigravity’ [which] controls the expansion of our universe, even though it has no discernible effect on scales less than a billion light-years.” Its numerical value is very small; had it been larger, galaxies and stars would not have formed.
5. Q: A ratio of two fundamental energies “imprinted” in the Big Bang and equal to 10^{-5} . If smaller, it would have resulted in an “inert and structureless” Universe or, if larger, would have resulted in a Universe dominated by black holes.
6. $D = 3$: The number of spatial dimensions in which we exist.

These number values, coincidental or not, are collectively necessary for the existence of the Universe in which we reside. Their formulation indicates one specific description of the anthropic principle. A more comprehensive description of the question of fine tuning and requirements needed for life in the Universe is provided by Friederich (2017). Smeenk & Ellis (2017) provide several considerations involving cosmology, fine-tuning, and the anthropic principle from philosophical and physics considerations.

Theological Connections

The anthropic principle, particularly in its form variously presented (Barrow & Tipler, 1986; Craig, 1990) as the Strong Anthropic Principle, seems somewhat similar to the teleological arguments for either a deistic or theistic deity as advanced over the years. The idea is suggested that because of a unique set of circumstances, in addition to the requirement indicated by the Weak Anthropic Principle that life must occur within a particular time frame, there are physical constants in the Universe that have particular values required for the existence and development of life. Although unnamed as such, the book *Human Destiny* (du Noüy, 1947) provided arguments of a similar nature. The classical teleological argument was provided by William Paley in his book, *Natural Theology* (1830; original publication, 1804), in which he suggests that a person discovering an intricate functioning watch might reasonably wonder about the existence of a watchmaker.

As indicated by the various forms of the anthropic principle, in order for life to exist, certain prerequisites must be met. Most formulations of the anthropic principle restrict life to a carbon base (sometimes termed carbon chauvinism), although there may be non-carbon-based forms of life, including intelligent life, that may occur in our known Universe (or in one of theorized multiple universes, unknown to us). With regard to carbon-based life, the universal conditions imposed by the Big Bang and its subsequent development

(ultimately) of life are restricted by the Scylla of chaos (and its disorder) and the Charybdis of regularity imposed by physical laws (Polkinghorne, 2007). Specifically, too much random change in biological evolution (or too little change) would lead to failure in natural selection. This is a consequence of the simultaneously restricted values, within narrow ranges, of the strengths of electromagnetism, the gravitational constant, the nuclear strong force, and the weak force. These constraints, as summarized by Polkinghorne, made possible the development of stars that produced elements heavier than hydrogen and helium, including (in particular) carbon.

According to various anthropic views, it is only through the coincidental confluence of a number of physical and chemical events, separated by varying amounts of time, that have resulted in conditions permitting the development of life—and, in particular, via evolutionary modification—intelligent life. The probable circumstances of this matrix of coincidences seems to be vanishingly small, since minor modifications of several of the physical constants and/or events would have made life, as we know it, impossible.

When viewing various interpretations of the anthropic principle, it is not uncommon to encounter, directly or indirectly, references to some kind of theological implication regarding how the arrangement of conditions necessary (or facilitative) for life originated. This may appear as a form of abstract intelligence in the Universe, a form of intelligent design or, alternatively, as theistic evolution following intelligent design that provided the original fundamental constants necessary for the existence of heavier elements, carbon-based life, and subsequent evolution.

Indicating that the Universe came into being, complete with critical constraining physical constants permitting star and galactic formation, synthesis of the heavier elements, planet formation (with some located at a so-called Goldilocks distance from a supportive star), the subsequent evolution of prokaryotes and eukaryotes (over thousands of millions of years) leading to complex and intelligent life forms through currently unknown random chance mechanisms is (for many) emotionally unsatisfying. Randomicity, alone, does not seem to answer how or why the Big Bang occurred.

As an alternative, there is the view that there must be some vaguely specified superintelligence, whether Laplace's demon, some type of deity, or some other (ad hoc) *deus ex machina* that started the cosmological chain of events leading to our query. This view, because of the Fries' trilemma (Popper, 2002), simply serves as a pseudoexplanation that provides a façade of explanatory understanding while ending active investigation (unless one

continues and answers questions about the source and origin of the superintelligence). This alternative view may be taken (as it has by some) to an extreme by identifying the “superintelligence” as the henotheistic deity of the Pentateuch—Yahweh. This view states that the hypothetical superintelligence that arranged (by establishing the critical physical constants) for, and initiated the formation of, a Universe, which consists of thousands of millions of galaxies (each containing millions of stars), is the same as Yahweh, the tribal deity of the Israelites.

Summary

Rare events happen more frequently than our conscious awareness and memory indicate. That events are differentially appreciated as rare may be a consequence of the relative ease of remembering them. Expected and easily chunked sequences are favored over unexpected, irregular, and more difficult to chunk sequences. Also, event probabilities for apparently unusual sequences are unlikely to be equal (or known) for each item in the sequence of separate events. Such a sequence is likely to be impossible to evaluate in terms of its overall probability.

There are beliefs that some improbable events are, nevertheless, highly predictable. This is, for example, a premise underlying the paranormal belief in precognition, which was investigated in the experiment described in Chapter 5.

In order for life to exist as we know it, there are certain requirements that must be met. These requirements have been collectively called the anthropic principle (as variously defined) and include the concurrent long-term existence of a favorable and stable (evolutionary-favorable) environment, stars and galaxies, chemical building blocks, and energy, among others. Various theorists have maintained that the collective requirements for life, as described by the anthropic principle, make its occurrence highly improbable without some external actor. As such, the anthropic principle has emerged as a modern teleological argument for a deity.

Chapter 7 – Considering Known and Unknown Event Probabilities

Just as William Paley (Paley, 1830) hypothesized that a designer was required for the existence of his famous watch, a second designer for Paley's designer would theoretically be required. But who is the designer of the second designer? We immediately get into the problem of infinite regress, known variously as Fries' trilemma (Popper, 2002) or the Münchhausen trilemma (Münchhausen trilemma, 2017), which also plagues the epistemological basis of the theological argument from the First Cause. Arguments, such as Paley's, seem to imply that the existence of complex objects is a very improbable event. This seems to be evident. However, other unnoticed events suggesting perceptual limits involving reality are also highly improbable. Some of these unnoticed, but improbable, events will be described in this chapter.

Generally Known Probabilities

Consider the following thought experiment: Flip a two-sided (heads/tails) coin 100 times and record the results of each flip. Assume, for purposes of this experiment, that each flip results in a random (neither biased nor pseudorandom) head or tail. Assume, also, that the trials from 1 to 100 are independent. These constraints are usually assumed, even though empirical evidence may suggest otherwise (Coin flipping, n.d.; Coin Tossing, n.d.). In viewing the results of this exercise, we see a set of events that could have occurred, on average, once in each 2.9 million ages of the Big Bang Universe, provided that this exercise is done at a continuous rate of 1 million sets (of 100 flips/set) per second. This kind of task was done (at a much lower rate) in an experimental session described in Chapter 5, the true random results of which are illustrated in **Figure 5.4**.

When viewing the results of a thought experiment (or real experiment), the high improbability of such a specific result sequence, for most people, does not seem to be that impressive until one reflects on the probability. As Hand (2014) mentions in his law of inevitability, something must happen. This seems to be the case among a set of mutually exclusive possible occurrences. We do not notice the highly unusual set of events in our hypothetical thought experiment (nor in a real experiment). If one encountered a sequence of 100 heads in such an experiment, that would be noticed and remembered (easily chunked, as described in Chapter 3) as a distinctly unusual event set, although it is no more unusual, probabilistically, than any other sequence. I picked this

thought experiment for the same reason I chose the precognition task in the experiment described in Chapter 5. It provides a computationally easy way of accurately identifying probabilities associated with particular sequences of events.

Everyday life provides us with more complex situations. We encounter successions of events, easily exceeding 100, each day with only some being identified with a specifiable probability. Some of the events are mutually dependent, while others are independent. It is probably hopeless to attempt to assign a probability of occurrence to any (lengthy) string of sets of occurrences. As a gross guesstimate, however, for a day's length of particular events in one's life, it is safe to say that the improbability is vastly greater than that for the coin-flip thought experiment mentioned above.

Returning, for the moment, to an observation about the replications of the precognitive experiment made in Chapter 5 and the probability indicated for a succession of 18,300 lefts and rights over the 183 sessions of 100 random trials per session; the probability of getting the particular sequence of 18,300 lefts and rights is given by a value of $2^{(-18300)}$. I regret that I did not retain a complete record of each session's sequence of 100 trials, so that I could provide an uninterrupted listing of the sequence of independent true random 18,300 lefts and rights. It would, however, be possible for me to generate another set of 18,300 trials (which I would transcribe to some permanent form). Since each session required approximately 20 minutes to go through 100 trials, one could (if done continuously) complete the task in a little over 2.5 days. I mention this not only to indicate my neglect in retaining information that might be of interest but, more significantly, also to indicate how anyone could, by using a two-sided coin (or a random bit generator), generate a sequence event that would occur with one chance in 7×10^{5508} . By considering a number of random physical parameters of the standard model contributing to the formation of stars lasting "billions of years," Smolin (1997, pp. 44–45; p. 325 for details) estimates the probability of such an event to be at most one chance in 10^{229} . By comparison, one chance in $2^{18,300}$, which approximates 7×10^{5508} for 18,300 coin flips, makes the estimated one chance in 10^{229} for star formation a sure thing in the cosmological roll of the dice, relatively speaking. A simple calculation reveals that 761 coin flips will generate a sequence resulting in one chance in 10^{229} or, similarly, 295 rolls of an unbiased six-sided die. It would appear that our retrospective evaluation of the probability of events that have happened needs to account for that existential fact.

Partially Known and Partially Unknown Probabilities

As a related and more speculative view of improbable events, Ali Binazir (2011) describes the likely sequence of events leading to our unique existence and attempts to quantitatively evaluate each necessary step along the way culminating in our existence. Tracing backwards (in his blog), he estimates, successively, the probabilities of one's parents meeting, their having a child (i.e., you), the combination of the sperm and egg at conception, the succession of ancestral heritage (not only to "Adam and Eve" but back through prior hominids, infra-primates, and all the way to the earliest eukaryotes), and indicates the result to be highly improbable. Staying within the human lineage and by estimating rough indicator probabilities for each step in this succession, Binazir arrives at an overall probability of one chance in about $10^{2,685,000}$ that each of us exists.

What seems to be ignored here is that, whether one is flipping coins, observing horse races or other sporting events, becoming aware of the results of a lottery, or recording the minutia of an extensive battle (in terms of which individuals were casualties and which were not), something must happen. This is indicated in Hand's (2014) law of inevitability. The examples that I have chosen to numerically evaluate (involving coins or dice) are examples that can be quantitatively and objectively evaluated. In contrast to these well-quantified examples, consider the hypothetical daily progression of events, including the successive encounters with, perhaps, 26 people (designated succinctly as person A to person Z). Person A may be the spouse; person B, a neighbor; person C, someone encountered (by accident or coincidence) on public transportation to the work setting; person D, the first of several people encountered in the work environment; persons E-W, others encountered in the work setting; person X, another person encountered on public transportation; person Y, a person encountered at a brief stop at a local pub; and person Z, the spouse (who, for computational simplicity and marital bliss, is the same as person A). For each of these persons, the probability of their encounter within a particular sequence (e.g., persons ... - M-N-O- ... and not ... -N-O-M- ...), which depends upon unspecified (and, as a consequence of ancestry, unidentifiable) joint probabilities deriving from coincidental successions of prior encounters, is, nevertheless, very (to extremely) low. The probability of a combination of events occurring in the sequence just described, I think, is likely to be vanishingly small—perhaps in the neighborhood of the probability of getting a specific succession of heads and tails in 100 coin flips (or less). Hand quotes Aristotle as saying: "The sum of the coincidences

equals certainty." But, something must happen. This suggests that the rules of probability as applied here, and in the universal case of anthropic concerns (that were described in Chapter 6), may not apply. Although the weak anthropic principle, possibly as a tautology, may arguably apply, the strong anthropic principle requiring certain specific universal fine-tuning conditions for life to exist seems more dubious (Barrow & Tipler, 1986, p. 21; also, see their "Final Anthropic Principle," pp. 23 & 658-659). In a section called "Does Improbable Fine-Tuning Unavoidably Call for a Response?," Friederich (2017) suggests that highly improbable fine-tuned conditions might appropriately be considered as "primitive coincidences" having no great probabilistic significance. He adds that flipping a coin N times generates a sequence having a probability of $2^{(-N)}$, which approaches zero as N increases. As I have indicated in Chapter 5, $N = 100$ flips results in a sequence so unusual that, if done 1,000,000 times per second, any particular sequence would occur (on average) once each 2.9 million ages of the Universe.

Table 7.1 illustrates the rapid increase in time required, on average, for a particular sequence of coin flips (heads or tails) as the sequence lengthens (but with a slower choice rate of one flip/sec).

Number of Coin Flips	Number of Distinct Alternatives	Number of Ages of the Universe Required (1 flip/sec)
1	2	$4.5925747 \times 10^{(-18)}$
10	1024	$2.3513982 \times 10^{(-15)}$
100	1.2676506×10^{30}	2.9108900×10^{12}
1000	$1.0715086 \times 10^{301}$	$2.4604916 \times 10^{283}$
10000	$1.9950631 \times 10^{3010}$	$4.5812382 \times 10^{2992}$
18300	$7.0618852 \times 10^{5508}$	$1.6216117 \times 10^{5491*}$
100000	$9.9900209 \times 10^{30102}$	$2.2939959 \times 10^{30085}$

[[Table 7.1](#)] *Time Required for a Specific Coin Flipping Sequence.* A brief table showing the amount of time typically required for one sequence to occur

for each of several varying sequence lengths of successive coin flips. *The value for 18300 corresponds to the total number of equivalent random bit generator binary choices made during the 183 experimental sessions described in Chapter 5 (but with the time required based on one flip/sec). These results are based on a Universe being 4.3548557×10^{17} seconds old (13.8 thousand million years old).

Largely Unknown Probabilities

A question that has been raised over probably thousands of years by many is the following: Are we alone in the Universe? I would guess that the frequency of occurrence of this question has increased over the past several hundred years as a consequence of the development of telescopes and the awareness of the increased size of the Universe. Optical telescopes, however, do not provide the capability to directly establish the existence of life (primitive or advanced) elsewhere in the Universe. Indirect indications, based on absorption spectroscopy of atmospheres in other planets, may be suggestive of life by detecting chemicals associated with familiar forms of life. Determining the complexity of life, so indicated, is not presently possible. In addition to the major advances of optical astronomy, particularly within the last century, there has been a corresponding development of radio astronomy. This has been made possible with the discovery of electromagnetic radiation, its associated spectrum of wavelengths, and the invention of radio in its various forms. Light has, of course, been known for millennia but has only been known for about 200 years as a form of electromagnetic radiation having wavelengths from 400 nm (blue) to 700 nm (red). Alternatively, but rarely, one can specify light in frequency terms, based on the reciprocal relationship between frequency and wavelength given by the equation $f = c/\lambda$, where f = frequency in Hz [cycles/sec], c = vacuum speed of light in m/sec, and λ = wavelength in meters. Although rarely used, the frequency range for light is from 4.2×10^{14} Hz (red) to 7.5×10^{14} Hz (blue). Interpreted either way, light is fundamentally a very short wavelength form of radio wave.

Radio astronomy was effectively born with the finding by Karl Jansky in 1932 of radio noise coming not only from thunderstorms but also from the Milky Way galaxy. The finding was initially a serendipitous discovery that manifested itself while Jansky was working on a practical radio noise problem interfering with radio transmission of telephone calls. His discovery of the galactic source of the noise is described in three publications, which are republished in W. T. Sullivan's (1982), *Classics in Radio Astronomy*. Paralleling the development of radio astronomy during the twentieth century

were advancements in commercial radio and television. These developments were assisted by electronic component changes from, e.g., tubes to transistors to integrated circuits. These components were incorporated into receivers (and other electronic devices) used also in radio astronomy.

With increasing awareness of radio noise (and, possibly, non-noise) signals from space, it appears that, as an alternative to traveling to extraterrestrial sites (e.g., the moon and planets) to find possible life, one could stay on Earth and listen for radio signals sent intentionally (from beacons) or incidentally (through radio/TV leakage) that might indicate some kind of intelligent life. Since radio (and TV) waves travel at the speed of light (in the vacuum of space), a civilization on a planet orbiting a star 10 light years away would possibly be detectable on Earth 10 years after the initiation of conventional AM, FM, or TV signals from them. Detection of these signals will likely require more sensitive reception equipment (including antennas) than are presently used, since Tarter (2001) states, "At current levels of sensitivity, targeted microwave searches could detect the equivalent power of strong TV transmitters at a distance of 1 light year (within which there are no other stars), or the equivalent power of strong military radars to 300 ly, and the strongest signal generated on Earth (Arecibo planetary radar) to 3000 ly, whereas sky surveys are typically two orders of magnitude less sensitive." Difficulties in reception of these signals might occur because of weakness (because of the inverse square law), an alternative mode of transmission unfamiliar to Earthlings, spread spectrum usage, or encryption (which for an advanced civilization may be prevalent). Correspondingly, incidental signals from Earth ("I Love Lucy") may be regaling some extraterrestrial individual somewhere within a radius of 65 light years, provided the signals are correctly detected, decoded, and interpreted.

Intentional (beacon) radio signals from Earth directed to some extraterrestrial civilization are likely to be stronger and modulated in less complicated ways (e.g., a continuous wave switched on-off in a sequence of bursts corresponding to prime numbers or some other scientifically significant sequence). There would be expected reciprocity by some theoretically advanced intelligent civilization in their attempts to fundamentally communicate with us (but with obvious delays imposed by the speed of light). This kind of investigation has been systematically initiated as the Search for Extraterrestrial Intelligence (SETI). Several sources of varying optimism about the existence of extraterrestrials have been published (Shklovskii, & Sagan, 1966; Morrison, Billingham, & Wolfe, 1977; Drake, Wolfe, & Seeger, 1984; and Shuch, 2011). More pessimistically, Tipler (1980) argued that extraterrestrial beings do not exist. "Optimistic" and "pessimistic" are terms

arbitrarily representing positive and negative belief in the existence of extraterrestrials. In the absence of hard evidence for either view, the optimistic argument (in favor of extraterrestrials) derives from the immense number of stars in the Milky Way galaxy and the similarly immense number of galaxies that exist, with each average star probably having a number of planets, some of which might be favorable to the development of simple life. Over an extended period of time, including a stable thermal environment, there is a possibility of complex (possibly intelligent) life developing. Modern findings of exoplanets reinforce this optimism.

The alternative (pessimistic) view taken by Tipler (1980) and renewed (Tipler, 2003) is based on rather different considerations. Starting with the same immense number of stars and galaxies, Tipler emphasizes a theoretical view, known popularly as the Fermi paradox (described below). Others have noted the absence of virtually any radio evidence for intelligent life elsewhere (other, possibly, than the Wow! signal in 1977 and, also possibly, FRBs, discussed below). The Wow! signal was a strong 72-sec 1420.46 MHz narrowband (< 10 kHz) radio signal, apparently coming from the direction of the constellation Sagittarius, and seems to be unexplained by any radio signal produced terrestrially (Wow! Signal, n.d.). The signal intensity increased monotonically over a period of 36 sec followed by a monotonic decline over the subsequent 36 sec. Since the telescope was fixed in position, the variation in signal strength corresponded to what was expected based on the Earth's rotation. The signal could have lasted longer than the 72 sec observed (and probably did). Numerous follow-up searches for the signal have failed to replicate it. In recent years another source of radio interest has been observed in the form of fast radio bursts (FRBs). Of particular interest is FRB 121102, which (unlike others) is a repetitive burster. As a consequence of repeated observations, it has been localized as emerging from a dwarf galaxy located approximately 3 thousand million light years from Earth (Scholtz et al., 2016; Gajjar et al., 2017). As a repetitive burster, FRB 121102 may have a higher probability of manifesting activity of an advanced civilization than a single FRB, which may indicate some kind of unrepeated astronomical cataclysm (Lingam & Loeb, 2017).

The Fermi paradox, described recently by Webb (2011), is based on the apparent absence of any hard evidence of the presence of extraterrestrials (although, as many have noted, absence of evidence is not evidence of absence). The name derives from a luncheon conversation (ca. 1950) with Emil Konopinski, Edward Teller, Herbert York, and Enrico Fermi concerning flying saucers and, more generally, extraterrestrials (Jones, 1985). At one point, Fermi raised the question, without elaborating, "Where is everybody?"

This generated laughter at the moment and became quoted and preserved for history as the Fermi paradox. The fundamental idea derives from the supposition that extraterrestrial civilizations are likely to be millions of years more advanced than humans on Earth and would be (possibly from necessity because of an expanding star in their solar system requiring an exit from their home planet) colonizing the Milky Way galaxy. Yet we have no clear evidence of their arrival (in whatever form) to Earth.

Frank Tipler (1980) provides an elaborate discussion of this absence of evidence in his argument for the nonexistence of extraterrestrials. Arguing from the possible necessity for escape from an unstable star, or other reasons, colonization of the galaxy should have been achieved, either directly by inhabitants of civilizations millions of years older (and more advanced) than we are or by an inorganic, self-replicating, independent, auto-programming, algorithmic, scavenging, and (effectively) immortal robot. The robot is designed such that it can be released and propelled out of its solar system where it can travel to distant stars, “forage” and replicate itself from materials from asteroids (or comets), and “live” an immortal life (or until the second law of thermodynamics eliminates all functioning). The robots are conceptually adapted from the von Neumann (1966) idea of self-reproducing automata and are occasionally referred to as von Neumann probes as an elaboration of his fundamental idea. These robots would be the products of a civilization that may be millions of years more advanced than we are. For comparison, we Earthlings currently (as of this writing) have a total of five non-reproducing space probes that are leaving (or have left) the solar system (Voyagers 1 and 2, Pioneers 10 and 11, and the New Horizons probe, in addition to some inert final rocket stages used to propel them).

Since 1960 a number of radio investigations have been made that have evolved into the current SETI activity. Given that electromagnetic communications have been developed over the past century in the form of radio and TV, and their transmissions are not limited to the Earth, it has been suggested that possible technologically intelligent extraterrestrial civilizations on planets orbiting other stars may be similarly incidentally transmitting signals. These signals might be detected by receivers on Earth using systematic surveys of likely radio frequencies. Because the Earth’s atmosphere is differentially transparent to parts of the electromagnetic spectrum, and other parts of the spectrum may be obscured by radio noise from stars or galaxies, attempts have been made to identify suitable frequencies to monitor. Since a thorough search of all frequencies would be difficult, a subset of optimal frequencies would be recommended. As it turns out, there is a spectral window, roughly between 1 and 10 GHz, characterized

by low noise and good atmosphere penetration. Cocconi and Morrison (1959) suggested a particular frequency, 1.4204 GHz (21 cm wavelength), that is the emission frequency of neutral hydrogen, both near Earth and presumably near (and known to) residents of advanced telecommunicating civilizations near distant stars. Frank Drake (Drake Equation, n.d.) systematically searched frequencies near 1.4204 GHz with the 25-m dish of the National Radio Astronomy Observatory (in West Virginia) directed at two nearby stars for several months during 1960 without success. Shortly thereafter (1961) Drake prepared his famous Drake equation for the purposes of stimulating discussion and research and as a way of attempting to quantify the possibilities of there being advanced communicating civilizations within the Milky Way galaxy. The resulting equation is given below:

Drake Equation

$$N = R \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

N = Number of broadcasting civilizations within the Milky Way galaxy.

R = Average rate of formation of stars per year in the Milky Way.

f_p = Fraction of stars with planets.

n_e = Average number of planets per star.

f_l = Fraction of planets with life.

f_i = Fraction of planets with intelligent life.

f_c = Fraction of planets with capability of electronic communication.

L = Average number of years a communicating civilization survives.

The first three factors in Drake's equation (star formation, stars with planets, and average number of planets per star) have received more plausible estimates in recent years as a consequence of modern terrestrial and satellite telescopic observations (e.g., Kepler). The remaining factors continue to be elusive regarding estimates. Because of the apparent rapidity of the development of primitive life on Earth following early stabilization of the environment (Marshak, 2013, pp. 331f), it seems that similar primitive life could have developed on a suitable planet located in a so-called Goldilocks (or animal habitable) zone from another star. Ward and Brownlee (2000)

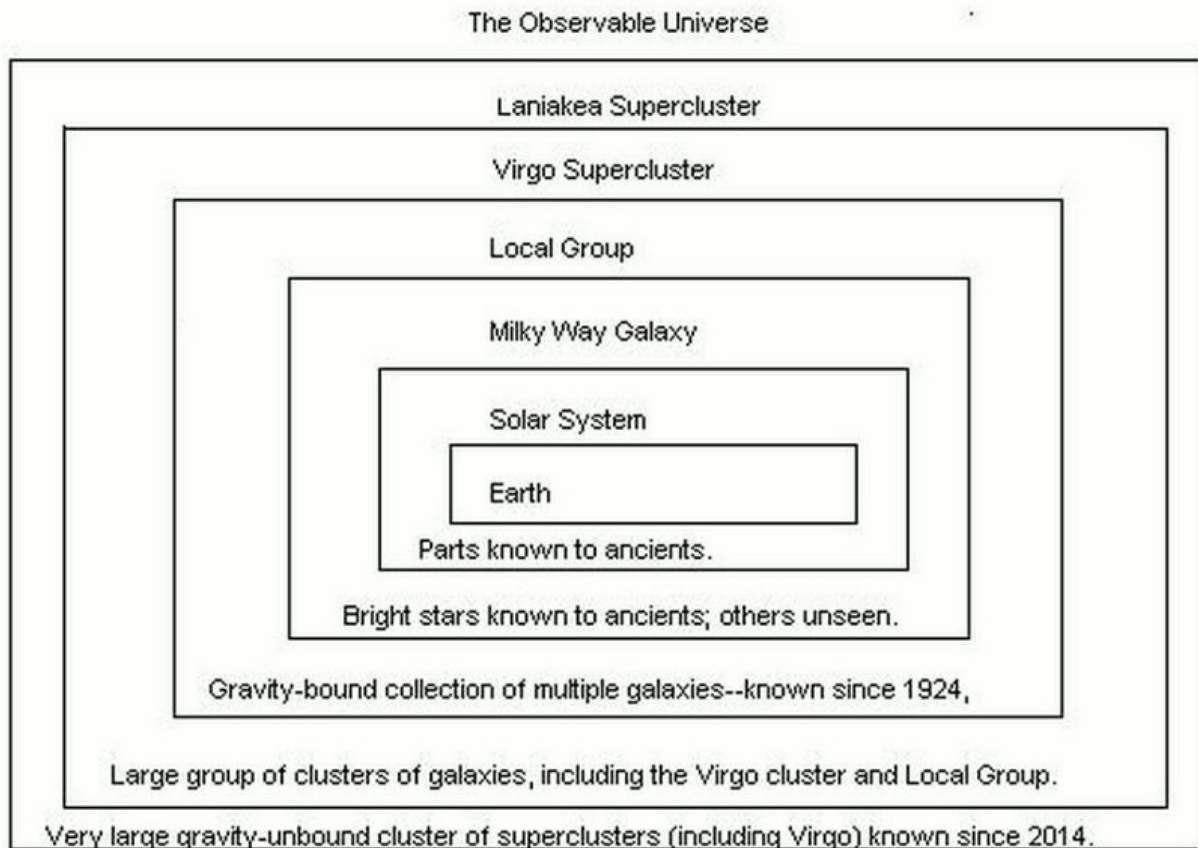
suggest a wider habitable zone, described as the microbial habitable zone, permitting life forms such as extremeophiles, primitive life recently found in deep regions of the ocean and other hostile environments, previously believed to be incompatible with life. Despite the success of Miller and Urey in producing appreciable amounts of several amino acids, fundamental for building proteins, by simulating early Earth conditions and by others using different chemical components to produce organic compounds (Shuch, 2011), there remains the problem of abiotic generation of self-replicating RNA and its more complicated chemical relative, DNA. This, of course, supposes that life started on Earth. Another view, called panspermia, maintains that life, or some of its significant components, originated elsewhere and arrived in primitive (UV-protected packages) but replicating form on Earth via comets, meteors, or some other mechanism. This relaxes the rapidity with which primitive life apparently developed over a comparatively short period of time if it did not originate on Earth but rather originated elsewhere. It does not, however, explain how life originated. It might, nevertheless, indicate a larger fraction of planets with life in the Drake equation.

The fraction of planets with intelligent life and with the capability of electronic communication seems to be a very small subset of those with life. Attaining the status of life may, once the self-replication mechanisms have been effected, be fairly prevalent, considering the increasing amount of biologically-significant chemistry that has been identified in interstellar space (Shuch, 2011). The experience of Earth, in which life appears to have begun within several hundred million years after its formation, indicates that life may (unless initiated elsewhere) develop quickly in its primitive form. This would include prokaryotes. Eukaryotes came much later. Over the history of human existence, intelligent life that includes electronic communication is an extremely recent development, existing as a consequence of many rational developments and an unknown number of serendipitous events.

Although some of the numerical components for this equation are better estimated than they were in 1961 (e.g., the fraction of stars with planets), most of the components are currently still unknown and debatable, and the equation seems to be an exercise in perceptual boundaries. The equation has, however, provided heuristic value in stimulating discussion. Controversy occurs when some have, *a priori*, inserted guessed estimates for some of the factors in the Drake equation in order to arrive at a value for N , the number of broadcasting civilizations within the Milky Way galaxy. There is, for the last four factors, virtually no evidence on which to base an intelligent or realistic guess. Circumventing this problem, either by finding evidence that improves the accuracy of one's guess about one or more of the unknown factors or by

finding direct empirical evidence of communication from a likely intelligent civilization, has been the two-pronged approach used in recent years. The latter approach has been dominant within SETI, using radio astronomy techniques, even though it has not been met with success. The absence of success may mean there are no civilizations to find, as Tipler (1980) argues. It may mean that the sample of stars investigated by radio astronomy may be insufficient to permit success (Tarter, 2001).

Perceptual boundaries have become more obvious in recent years when attempting to view distant astronomical objects. For some of the most distant objects, quasars, the red-shifted spectral lines suggest radial velocities (based on Doppler analysis) greater than 90% of the speed of light. Abell (1980, pp. 362f) mentions that, since the red-shifted spectra are from quasars associated with distant galaxy clusters of known distance (by other measures), the apparent Doppler red shift is likely to be an accurate indication of their distance. As one moves outward from the Earth in **Figure 7.1**, the successive increased use of recent technology (telescopes, etc.) has correspondingly increased our knowledge of the boundaries of the Universe. Quasars would be located beyond the Laniakea supercluster. **Figure 7.1** is limited to the observable Universe, to which we are optically and electromagnetically restricted (via radio and its related forms), with the finite velocity of light imposing a distance limit out to a maximum of about 13.8 thousand million light years (i.e., back to the occasion of the Big Bang).



[Figure 7.1] *Expanding Views of the Universe as Seen across Centuries with Improvements in Technology*

Summary

In the evaluation of the significance of apparently rare events of low estimated probability, it is helpful to have clear knowledge of the actual probabilities of those events. In this chapter I have described three general sets of events. These sets vary in their probabilities and, more significantly, in the accuracy of our knowledge of their probabilities. The first of these three is illustrated by the outcomes of true random phenomena, as in the case of flipping an unbiased coin or rolling an unbiased die. The probabilities so identified are objectively stated (in advance) and generally agreed upon as generally known probabilities. We are able to clearly specify, either before or after the event, what the probability is of that event occurring. For example, the succession of either heads or tails obtained by flipping an unbiased coin 20 times may seem to be a trivial event, but this sequence has less than one chance in a million of happening (or happening again in the same sequence during 20 more flips).

The second set includes those interpretatively more complex and ambiguous partially known or unknown probabilities that are estimated in retrospect

(usually) and subject to random factors, combined with partially known and unknown confounding determinants. Typical of this approach is the attempt to analyze some apparently unusual event in terms of the probability of its occurrence relative to alternative events. For example, what is the probability that I would happen to see a bluebird on a tree limb before me? This question must consider the dependent and independent probabilities associated with the time of day (day or night), my being in front of the tree, the time of year (seasonal migration), and my vision (good or bad), etc. What I have just described is the relatively easy part. When you consider the additional probabilities that I am in this region of the country where bluebirds may be, that I exist and have attained a certain age, that my parents met (and their parents also met, etc.), one can appreciate the ambiguity and decline of overall probability that the event described actually occurred.

The third set describes probabilities, most of which are unknown. I illustrate this by reference to the Drake equation used for estimating the number of likely communicating civilizations within the Milky Way galaxy as part of the search for extraterrestrial intelligence (SETI). Some of the factors comprising the equation may be plausibly estimated but several remain completely unknown. The equation was advanced for its heuristic value and has been actively investigated over the years. Some of the activities and findings related to this search are described.

Chapter 8 – Sensory and Perceptual Augmentation and Substitution

Over the course of human history people have sensed and, consequently, perceived the environment surrounding and within them via the naturally occurring human senses. With increasing age the individual may experience less sensitivity or functioning resulting from changes in existing sense organs. There are, also, variations in sensitivity or functioning across individuals, ranging, for examples, from reduced vision (nearsightedness, farsightedness, presbyopia, and cataract formation, etc.) and hearing (idiopathic, noise or chemically induced deafness, and presbycusis, etc.). Other senses vary in their sensitivity as well. In some cases the individual experiencing a deficiency (compared to other people) in a particular sense simply had to continue with the deficit. In the sensory and perceptual history of the world, however, some developments have occurred, accidentally or by research design, to reduce the deficiencies experienced by those with abnormal and deficient sensory capabilities. The older class of such developments can be described as sensory and perceptual augmentation. Recently, a second approach has been advanced in which a deficient sense has been supplanted by providing an alternative sensory input, either through mechanical or electronic means, to a part of the body not deficient to some modified (or alternative) sensory input. This practice has become known as sensory substitution in which one alternative sense substitutes for a defective sense. Examples of these categories follow. In many cases this approach relies upon cerebral plasticity of function, whereby a function normally localized to a particular part of the brain may acquire functionality in another part of the brain not normally so utilized. As a result, limitations imposed by malfunctioning of a sense organ may be reduced in severity.

Sensory and Perceptual Augmentation

Sensory and perceptual augmentation may be desired for a variety of reasons. For most people the desired augmentation is not in order to compensate for pathological abnormalities in individual sensory capability but, instead, to amplify or improve upon existing sensitivity. Devices that accomplish this include hand placement behind the pinna of the external ear to hear fainter sounds from a specific direction and positioning the fingers of the hand before the eye, forming a crude "pinhole" in order to increase the effective depth of field, thus improving vision for objects too close for effective visual accommodation. Technologically, these two behavioral procedures have been

(initially) replaced by the ear trumpet (for hearing) and opaque objects with a small pinhole (or set of pinholes) present (for vision), respectively. Although the use of the hand to amplify sound seems to be relatively well known, the use of a pinhole for assisting vision is not. I have noticed that this idea seems to be reinvented every two decades (or less) in the form of "pinhole glasses." It does work but not as well as one might hope, since it reduces brightness. The reinvention rate seems to parallel that for glasses with different color filters for the two eyes, thus providing a rudimentary form of color vision for persons with some types of color blindness.

One form of visual augmentation that has been around for a long time is that of lens magnification. It is not evident where this originated. My guess is that it may have been noticed by some obscure Neanderthal individual who observed that water droplets, formed through surface tension on a leaf, appeared to make the surface underneath the droplets larger than it actually was but never published his observation (possibly one of the earliest instances of "publish or perish"). Over the years since, with the development of glass and other transparent substances modifiable in shape, individual magnifiers, singly or in combination, have been used as magnifiers, eyeglasses, telescopes, binoculars, microscopes, and other optical devices that facilitate or augment vision. Intraocular implants for cataract lens replacement have been used for decades.

Perhaps, in a second category, one would include the quite varied forms of television, ranging from closed circuit TV (CCTV) to being able to witness, via TV, the Cassini spacecraft pass through Saturn's rings on its final day. Highly developed technological forms of sensory augmentation would include scanning and transmission electron microscopy, algorithms for various forms of computed tomography (CAT and MRI scans), and optical coherence tomography (OCT) scans. Another category to be considered would be the use of support or probing mobility (long) canes used by blind people and specialized glasses for those with age related macular degeneration (AMD) that move and enlarge visual images to peripheral parts of the retina that remain functional.

Augmentation of hearing has advanced from the days of the ear trumpet. For people, in general, we have radio, telephones (wired and cell), headphones, earphones, loudspeakers (and associated amplifiers), and a variety of computerized audio devices. For those with subnormal hearing in the form of presbycusis or, as a consequence of attending too many rock concerts, there are hearing aids (behind the ear or in the ear) and cochlear implants available. Telephones and other devices can provide flashing lights that are correlated

with auditory signals not detectable by persons with severe hearing loss.

The preceding instances illustrate ways of facilitating normal (or near normal) vision and hearing. There are, also, ways that have been developed to augment other normal senses. Possibly, the addition of a distinctive odorant to natural gas and flavor enhancers to foods would qualify in this category. Most of the clearly identifiable work, however, seems to involve either vision or hearing.

Sensory and Perceptual Substitution

Tactile substitution for visual absence or loss has been utilized in various ways for centuries. The use of mobility canes provides both tactile and acoustic information assisting a person without sight. In an attempt to reduce nocturnal battlefield casualties on the field because of lighting being used to read messages, thus revealing their location to enemy combatants, Charles Barbier de la Serre invented a system of "night writing" that consisted of letters (and some groups of letters) being encoded in the form of raised dots in a 2 X 6 matrix that could be felt and decoded with a (large) finger. Because the system was not easily readable by many with smaller fingers, the system failed to be generally accepted. The young blind student Louis Braille (who was asked to test and evaluate this system), however, considered the fundamental idea to have merit and revised it into a simpler 2 X 3 matrix of raised dots. This became known as the Braille system and has been widely accepted in multiple countries and languages. Developed in the first half of the nineteenth century, the Braille system is an early example of an effective sensory substitution system in which tactile stimulation provides sensory input for what (for others) would be visual input.

One recent approach to sensory substitution, in a way analogous to Braille, is to utilize embossed symbols representing letters and other characters in Morse code in a format that can be sensed through one finger in a single region (as in the case of Braille). Bodnaryk (n.d.) has proposed what he identifies as "tactile Morse code," which accomplishes this. Standard characters (letters and numbers) are easily interpreted by anyone familiar with International Morse code, although punctuation, foreign language accents, etc. are newly defined in this tactile Morse system, thus requiring learning of these additional symbols. For fundamental characters (letters and numbers), tactile Morse code seems feasible. I can sympathize with the difficulties involved for extensions to other characters. I have written a computer program that converts either typed text into auditory Morse code or reads and converts an

ASCII text file into auditory Morse code at operator-adjusted speeds from 1 to 80 words/minute. The program includes letters (including umlauts), numbers, and commonly used punctuation, all of which are defined by International Morse code. For a person proficient in Morse code, there is no additional learning required. The program, however, is based on MS-DOS and works on computers running MS-DOS (or are backward compatible) up to and including (16- or 32-bit) Windows XP with an internal speaker. When running the program with an existing text file, one is asked to enter the file name and desired speed and the Morse output ensues.

Several decades ago, for purposes of assisting me in class in discussing sensory substitution, as illustrated by Bach-y-Rita (1972), I designed and constructed a visual to auditory scanner (Auditory Visual Scanner). This prototype included a 5 X 5 square matrix of 25 photometrically matched (CL 905 L) photocells (with associated electronics) that effectively scanned objects located in front of an Exakta SLR camera lens mounted on the scanner. The front of the scanner had an attached bayonet mount permitting the interchange of lenses of different focal lengths. The auditory output consisted of 5 simultaneous tones of distinctly different frequencies (360, 560, 832, 1409, and 1690 Hz), each within its own critical band (Green & Swets, 1966), and determined by fixed resistors and capacitors in the emitter leads of unijunction transistor relaxation oscillators. Outputs of the oscillators were connected through vertical sets of 5 photocells (corresponding to 5 vertical positions in the visual field of the scanner) to the audio amplifier. Brightness was translated into audio amplitude at each tone frequency, and frequency corresponded to the vertical position in the visual field. The set of 5 concurrent tones for each vertical slice of the visual field was selected for information load reasons suggested by Miller (1956). The scanner was designed to move, from left to right in the visual field of the scanner, through the 5 separate vertical slices at an operator-adjusted rate such that a full scan, in order to meet requirements of the duration of echoic memory, could be easily accomplished within 2 or 3 seconds. At the end of each scan (of 5 successive vertical slices), a single tone of a distinctively different frequency (3400 Hz) was sounded to indicate completion of the scan and initiation of the next scan. The audio output could be delivered through headphones or, for instructional illustration, through an external audio amplifier to a speaker. The scanner (which provided brightness information across its visual field but neither color nor distance information) was developed as a proof of concept and has been used in numerous classroom demonstrations but not used in research. Appendix B includes illustrations of the Auditory Visual Scanner.

Bach-y-Rita & Kercel (2003) have provided an update to the sensory

substitution work described 30 years previously by Bach-y-Rita (1972). Their emphasis is on brain plasticity and its functioning with vision-to-auditory and vision-to-tactile (vibratory or electrical) sensory substitution. Meijer (1992) describes a more sophisticated audio substitution device incorporating CCD cameras with an audio output and a displayed visual output on a computer monitor. His device has greater resolution (initially 8 X 8 pixels with 3 amplitude levels and, subsequently, 64 X 64 pixels with 16 amplitudes for the resulting output) as compared to my Auditory Visual Scanner (with 5 X 5 pixels and a relatively continuous auditory output level indicating brightness). Meijer used a "recognizable synchronization click" separating each complete scan, which corresponds to the single 3400-Hz tone I used to serve the same purpose. Another difference was his use of time limited (for the duration of the pixel column being scanned) sinusoidal oscillators, while I used five unijunction transistor (UJT) oscillators, with each oscillator frequency indicating vertical position within each column being scanned. His auditory amplitude output was one of three (initially) or sixteen amplitudes, whereas mine was essentially continuous and operator-controlled electronically (through an auditory potentiometer) or optically (by adjusting the lens aperture).

Echolocation by means of auditory cues has been used at least since the widespread adoption of mobility canes that, when tapped on a hard substrate, produce short pulses of sound coming both from the end of the cane and, also, from objects nearby reflecting that sound with varying time delays (and amplitudes), depending upon distance. The significance of this was not fully realized until the parallel work of Griffin (1958, 1959) into animal sonar capabilities, particularly in bats, and the finding by Supa, Cotzin, & Dallenbach (1944) that blind humans relied on auditory feedback in order to avoid obstacles and not some kind of "facial vision" (see Griffin, 1958, pp. 299–303 for examples) that utilized pressure sensitivity of the skin, previously believed to be responsible for obstacle avoidance by totally blind people. Prior to the experimental finding by Supa, Cotzin, & Dallenbach, it was popularly believed that those blind individuals who seemed to be particularly accomplished in their individual navigation (without a mobility cane for assistance) had some kind of residual facial sensitivity that permitted this, and it was not a consequence of auditory cues. This belief was also shared by those who were blind (Griffin, 1958, pp.299–303; Supa, Cotzin, & Dallenbach, 1944). Supa et al. (1944) established that auditory cues were critical for effective obstacle avoidance by their two blind subjects. It was also found that normally sighted, but blindfolded, subjects improved in obstacle avoidance as long as hearing was not obstructed.

Since echolocation occurs naturally among bats, dolphins, and some whales and birds (among other animals), it may not be completely appropriate to include this capability under sensory substitution, as if it were a separate sensitivity. There is, however, the effective substitution of hearing sensitivity replacing or augmenting another, namely vision. It seems, therefore, to be appropriate. Echolocation does provide sensory information similar to that provided by normal vision but through an alternative sense organ. The quality of the auditory feedback varies from single clicks, generated by tapping the end of the mobility cane (or through the use of shoes with metal taps), through the emission of a constant ultrasonic frequency (CF) in a short burst, to the use of a frequency varying "chirp" (FM) emitted by some bats (Griffin, 1958). By way of definition, ultrasonic means above the normal human frequency limit of hearing (typically given as 20,000 Hz [or, in older literature, 20,000 cycles/sec]); infrasonic means below the normal human frequency limit of hearing (20 Hz); and sonic includes those frequencies (20 Hz to 20,000 Hz) that can be heard by young adult humans with normal hearing. As Griffin (1958, pp. 123–126) summarizes (based on research done by others), in addition to bats, mice, voles, deer mice, and other small mammals, hearing extends into the ultrasonic range of frequencies. He suggests a tentative generalization (or working hypothesis) that smaller animals are more likely to hear ultrasonic frequencies, whereas large animals are sensitive to sonic frequencies.

By utilizing (in the simpler case) a discrete mobile cane tap (or a succession of taps) or a brief constant frequency (CF) ultrasonic tone which terminates prior to the return echo following its emission, distances to various reflecting objects in the environment can be estimated. Sound velocity in dry air at 25 degrees C is approximately 346 m/s (or 1135 ft/s). In water (depending upon temperature, salinity, pressure) the velocity of sound is approximately 4.3 times as fast. For an object located one meter away, sound from a tap or brief pulsed ultrasound would require $2/346$ second or about 6 ms to go from and return to the human or bat, thus providing a cue as to distance. Arrival times for the two ears will differ if the object is off to the side, thus providing additional partial location information. In the case of a CF signal, movements by the object can provide (from Doppler shifts) additional information about relative velocity (between source and target). Target object characteristics (hard or soft, uniform or nonuniform, large or small) providing distinctive echoes can be detected by hungry bats wishing to capture moths and avoid walls. Because of certain physical and physiological limitations, some of this information may not be provided. For example, loud emissions may generate what is known as forward masking, and the return echo may be too weak for its perception. Duration of the emitted pulse may be inadequate for Doppler

determination of relative movement. Stevens and Davis (1938, p. 102) indicate that a tone of intermediate audio frequency, 500–5000 cps [Hz], must be presented for 10–15 ms in order for its pitch to be perceived by humans. The acoustic reflex attenuates sounds (including echoes) occurring after 10–100 ms following loud, pulsed sounds in humans. Nevertheless, various animals, including humans, are able to echolocate with available acoustic cues.

Although many human blind individuals may be (and frequently are) unaware of the contribution of acoustic cues in facilitating their navigation, recent developments have included the use of a particular cue—the palatal click—as a means of providing a well-defined discrete cue that increases effective mobility. Palatal clicks occur in some languages but, as used here, are clicks not intended to provide phonemic content but are used to generate navigational sounds for echolocation. Although linguistic definitions of palatal clicks seem (to me) to vary, as used for the purpose of providing auditory feedback, the click is generated by pressing the tongue against the hard palate, thus forming an effective vacuum, and rapidly withdrawing it in a downward and backward direction. This, with practice, generates a sharply defined click having a measured amplitude at a distance of 30 cm from the mouth of greater than 80 dBA. Daniel Kish, who may be found in numerous videos on YouTube through a search of his name, is a very accomplished user of this procedure. His videos, among others, will illustrate its use in navigation by echolocation. In contrast to the immediate audio changes I can detect with my Auditory Visual Scanner (previously mentioned) while it scans different patterns, my inexperienced hearing does not provide me with clear echoes to my palatal clicks, measured to be slightly more than 80 dBA (@30 cm) and to have a duration of about 3 ms (as measured with an Akai Model DM-13 dynamic microphone connected to a B & K Model 1431 oscilloscope). By way of rough comparison, the little brown bat (*Myotis lucifugus*) emits a variable fundamental frequency that declines over a period of about 2.3 ms from 78 to 39 kHz (Griffin, 1958, p. 205). Fenton (2004) adds, with implications for other organisms monitoring such emissions, "Information leakage is the second big disadvantage. An echolocating *Myotis lucifugus* searching for prey produces 110 dB (SPL @ 10 cm) 4-ms-long signals at 50-ms intervals, continuously broadcasting its position and course to listeners that can hear signals dominated by sound in the 40 to 80 kHz range." Griffin observed, using a specialized condenser microphone with an oscilloscopic display of acoustical output from his bats of different species, that there were harmonic frequencies generated. How high in frequency these harmonics effectively occurred could only be speculated because of the technological limits of his equipment. The hearing range of bats apparently

typically exceeds 100 kHz with a likelihood that these lower harmonics may also be influential in echolocation.

For purposes of echolocation, the acoustic emissions of bats are typically short (so that overlap of sent and return signals is avoided) and emitted at high frequencies (>60 kHz, up to 200 kHz), thus providing better target resolution, although higher frequencies may suffer greater atmospheric attenuation (Fenton, 2004). A constant frequency of sufficient duration may provide, as a consequence of Doppler shifting of the return echo, information about the relative velocity of the bat and its target. Differential return echo amplitude to the two ears can indicate target lateralization. Although I have no forward masking data for bat hearing, one would theoretically suppose that forward masking, occurring shortly after emission, would be compensated for by greater echo amplitude for near objects.

There are limitations occurring with echolocation. For Doppler detection, the pulsed duration must be long enough for pitch detection. This duration, as already noted, for humans is approximately 10-15 ms for midrange tones (Stevens & Davis, 1938, p. 102). For bats, having a greater spectral range of sensitivity, the necessary duration may be less. Fenton (2004) suggests that lower (but still ultrasonic) frequencies may be less attenuated by the atmosphere but are more likely to be detected by target insects, which have sensitivity to the lower frequency range and may take countermeasures to avoid the predator. Learning to use cues provided by echolocation is not instantaneous, as in the case of the scanning techniques demonstrated by Bach-y-Rita (1972), Bach-y-Rita & Kercel (2003), and Meijer (1992), which do, however, show improvement with practice. Supa, Cotzin, & Dallenbach, (1944), while not looking for it, found improvement (over weeks of trials) in their blindfolded, normally sighted, subjects and reported this as an incidental observation forming the basis, subsequently, of an active movement to incorporate echolocation as an aid for locomotion in blind humans. In a survey Thaler (2013) concluded, based on responses, that echolocation can serve as an adjunct to the use of the long (mobility) cane and not as a replacement.

Thaler, Arnott, & Goodale (2011) not only studied behavioral responding using echolocation feedback but also explored neurological activity using functional magnetic resonance imaging (fMRI) that might occur along with echolocation activity. Four subjects were tested. One 27-year-old “early blind” (binocular vision loss at 13 months of age as a result of retinoblastoma) subject and one 43-year-old “late onset blindness” (vision loss at age 14 as a result of optic nerve atrophy) subject, both of whom used echolocation daily,

“enabling them to explore cities during traveling and to hike, mountain bike or play basketball,” served as experimental subjects. Two sighted “non-echolocating” subjects served as controls. All were right handed. Recorded echolocation stimuli (with or without echoes) were delivered via MRI-compatible insert earphones and responding was recorded by finger accessed keypads. A Siemens 3-Tesla whole body fMRI “... revealed reliable blood oxygen-level dependent (BOLD) activity in auditory cortex as well as in the calcarine sulcus and surrounding regions of ‘visual’ cortex in ...” both experienced blind subjects but no calcarine cortex activity in either of the sighted control subjects. Additionally, there was evidence of contralateral calcarine (Brodmann area 17) activity in the early blind subject but not for the (less experienced) late onset blindness subject. These findings are suggestive of cerebral plasticity of function.

Although location resolution is probably, and inevitably, going to be limited to values less than those encountered in normal vision, the research described by Thaler et al. (2011) suggests that there may be improvements to the current utilization of echolocation feedback in the future. These developments may indicate a less pessimistic consequence to acquired (and congenital) blindness by providing a partial analogue to vision.

Summary

Some compensating methods and corrective devices used to facilitate sensory awareness for people with normal sensory capabilities (eye glasses, binoculars, telescopes, radio, and TV, etc.) and for people with sensory limitations (presbyopia and presbycusis, etc.) are described. In addition to visual and auditory limitations, adverse limitations to other senses (odor blindness and taste blindness) are mentioned. These compensating methods may, generally, be in the form of sensory augmentation in which improvement of existing senses of vision and hearing, etc. may be achieved by the use of various technical devices facilitating the sensory capabilities of people with normal sensitivity. Alternatively, there are some behavioral methods, in addition to electronic devices, that have been developed as forms of sensory substitution that can help compensate for defective senses. Hearing loss can be compensated for by the use of hearing aids, acoustically stimulated light flashes, or (more directly) the installation of a cochlear implant that bypasses the external and middle ear components in order to directly stimulate the auditory nerve.

Sensory substitution for visual inputs can be achieved by several described

methods, including Braille, various electronic systems converting parts of the visual field into auditory or tactile stimulation, and the use of echolocation feedback in a way analogous to that used by bats.

Chapter 9 – The Limits of Intuition

Apophenia and Pareidolia

Apophenia is a form of misperception of reality. For example, suppose you are in the jungle, hear a growl, and immediately interpret that growl as something about to pounce upon and eat you. Suppose that the growl you heard, unknown to you, is just the ringtone coming from the cell phone of your guide. The fact that you thought you were about to be something's dinner would be a misinterpretation of reality and therefore an instance of apophenia. Apophenia is very common. Visualizing a secret code underlying a religious or mystical text, seeing patterns in cloud formation, attending to stimuli supporting one's beliefs while neglecting those that do not, and "being on a roll" as a result of a sequence of successes in gambling are examples of apophenia. A related cognitive phenomenon is pareidolia, which is visualizing faces in coincidental arrays of visual stimuli. Confirmation bias, superstitions, and prudent caution can result from apophenia.

In everyday life we experience the world through our senses. They contribute to the perceptions that we form based, in part, on sensory inputs and whatever accumulated biases that may modulate the consequent appearance of reality. I have indicated in Chapters 1 and 2 some of the physical and physiological limitations of our sensory input (e.g., the very limited amount of the electromagnetic spectrum that is visible and the limited auditory frequency range we hear) and in Chapters 3 and 4 some of the additional cognitive constraints that limit the veridicality of our perception of the world. Additionally biasing our perceptions are the impositions of cognitive modifiers. In some cases this imposition may be valid, whereas in others it may not.

Consider String B of Chapter 6: H H H H H H H H H H. If one obtains a series of 10 heads in 10 flips of a coin, it can be interpreted either as an event that happens once every 1024 sets of 10 flips (on average) or as a significant event indicating something extremely unusual or paranormal. Given that it is a two-sided (heads or tails) unbiased coin generating the string of heads, the latter hypothesis suggests apophenia. This kind of interpretive patterning can be applied to more complex series when viewed retrospectively. Consider: H T T H T T T H T T T T T H T T T T T T T H. An observant individual may notice that the symbol T appears 2, 3, 5, and 7 times with an H separating each increasing prime number count. Once a pattern is detected, it may not be

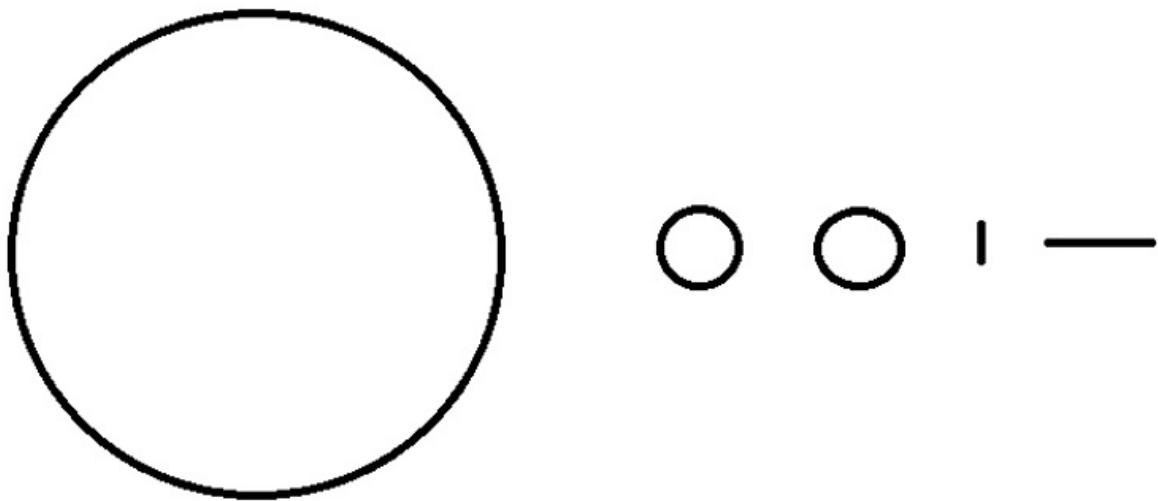
necessary for it to always be present in order to reinforce (reward) the interpretation. A well-established principle in experimental psychology is that of the partial reinforcement effect in which a behavior becomes stronger (e.g., more frequent) if it is not reinforced (rewarded) every time. This is related to the principle of confirmation bias in which the person searches until the presumed pattern is found, thus "fueling" the continued development of the bias. Conspiracy theories are good examples of this. In some cases apophenia may signal the initiation of some form of mental disorder (e.g., schizophrenia, as suggested by the German psychiatrist Klaus Conrad). Its generality is, however, much more prominent in normal (non-pathological) human experience.

Conspiracy theories are examples of apophenia. Components of a conspiracy theory (whatever it may be) will likely consist of some factual statements that are true while others may not be true (or are unsupported by evidence). The selection of the components is subject to confirmation bias with those components that fit the bias being preserved while those that do not fit may be forgotten. The resulting (and surviving) collection of factual statements (true or not) allow conclusions to be reached that are not generally accepted by everyone. As such, a conspiracy theory becomes an instance of apophenia and may be clearly countered by other assertions having more validity.

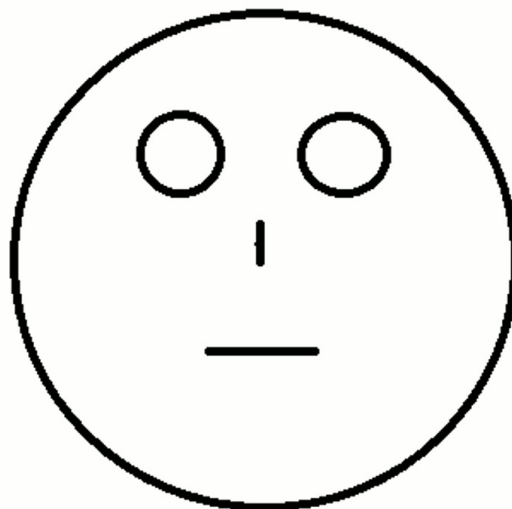
Examples of conspiracy theories include landings (crashes) of unidentified flying objects (UFO's) indicating the existence of alien extraterrestrial life encountering some humans; a New World Order, consisting of highly influential (but secretive) individuals who have conspired to actively control modern civilization through manipulated economies and wars; various medical theories suggesting the dangers of fluoridation and vaccines; modern theories of a flat Earth; and the staging (by NASA) of a moon-landing hoax. For information about these (among many other) conspiracy theories, see listings in Wikipedia (or through a Google search of conspiracy theories). What these conspiracy theories seem to have in common is the retrospective marshalling or "cherry picking" of facts (true or not) that support the theory. Arranging facts (true or otherwise) in this way can mold the theory into a meaningful, potentially more believable, story. It helps supporters of a particular theory to be able to summarize it into a convenient STM (short term memory) label (or chunk). A century ago the terms "Area 51," "9/11," "birtherism," "Moon landing hoax," and "New World Order" would have had no distinctive meaning as they do today.

Now, consider a collection of apparently unrelated stimuli. One set is shown in **Figure 9.1**. This shows frequently encountered individual stimuli from

everyday life experience. A rearrangement of the same stimuli is shown in **Figure 9.2**. This rearrangement illustrates what many might regard as a face, even though a large number of subtle facial details are absent.



[[Figure 9.1](#)] *A Set of Unrelated Common Symbols Appearing without Apparent Connected Meaning*



[[Figure 9.2](#)] *The Same Components of Figure 9.1 Rearranged in Figure 9.2*

Figures 9.1 and **9.2** show the effect of the modification of a non-facial image into a facial image through the placement of the same relatively common visual elements encountered in the environment into a different pattern. This different pattern is frequently (with distortions) encountered in everyday life and partially suggests a basis for pareidolia (seeing faces in non-face stimuli). One may speculate that, as a consequence of frequent encounters in everyday life with human (and some animal) faces having eyes, a nose, and mouth in the same relative positions, repeated memory traces have formed Hebb's

(1949) cell-assemblies (as indicated in Chapter 3) and hippocampal synaptic connections with subsequent cortical storage.

Of possible related interest is the finding of Quiroz Quiroga, Reddy, Kreiman, Koch, and Fried (2005) of individual neuronal responding in pharmacologically intractable epileptic patients reacting via implanted electrodes (placed in order to identify seizure foci) in the medial temporal lobe (in the hippocampus, among other sites) to pictures of various famous individuals, including Bill Clinton, Michael Jordan, Julia Roberts, Kobe Bryant, Halle Berry, the Beatles, and Jennifer Aniston. The highly specific (each patient responded uniquely to pictures of a famous person) neurological responses from some neurons are reminiscent of the somewhat less specific reports of Penfield and Roberts (1959) as mentioned in Chapter 2.

Apophenia and its related category, pareidolia, embrace a large range of phenomena. In addition to the faces that may be omnipresent, there are attempts by some to elicit meaning from randomness, as in the Rorschach inkblot technique. There are the Martian canals and stellar constellations; the gambling fallacy in which one expects a change after a series of one type of outcome (e.g., after ten heads, the next flip has greater probability of being a tail); sightings of UFO's; and assessments from numerology or astrology. Humans (and, probably, other animals) seem to be attempting to account for what is perceived in their environment, and they do so by organizing collections of (in some cases) random stimuli into meaningful interpretations. This may have, as some have suggested, evolutionary value in identifying what may be predators or other dangerous circumstances. "Patternicity" is the name coined by Shermer (2008) for "the tendency to find meaningful patterns in meaningless noise." When the circumstance is innocuous, it would be interpreted as a false alarm (or false positive). In statistics this is called a Type 1 error. In order to reduce the frequency of false positives without excessively elevating false negatives (known in statistics as a Type II error), methods have been developed that permit one to specify the probability of a false positive (or Type 1) error.

As I have indicated in Chapters 5, 6, and 7, exceedingly rare events happen regularly. This view is discussed and illustrated (for rare events) by Hand (2014) in his book, *The Improbability Principle*. What is not noticed, until one starts thinking about an event and its possible alternative happenings (which did not occur), is the rarity of the noticed event. This rarely becomes evident unless one considers the sequence of contributing factors that must have occurred prior to the event's occurrence (and necessary for the event's occurrence). At this moment the individual may (and, apparently, frequently

does) think that something non-random must be responsible for the event's occurrence. This, I speculate, is the initiation of apophenia. It occurs in the absence of conscious awareness of the fact that everything that happens is exceedingly rare—not just the phenomenon being considered.

Disease, Deception, and Mass Murder

There are circumstances in which one may wish to apply considerations of apophenia in a rigorous manner in order to deduce or clarify some phenomenon not obvious to casual inspection. I will describe three (of many possible) examples of such an attempt. These are related to a concept termed “intuitive statistics” by Daniel Kahneman and his collaborator, Amos Tversky (Kahneman, 2011). The first of these involves medical diagnosis and illustrates our perceptual limitations when confronted with data composed of several parts that must be cognitively combined in order to make a rational interpretation of a person's medical status. The second example is a brief description of the use and interpretation of polygraph results. The third example concerns the prediction of violence in the form of mass murder and is of considerable political concern in the United States (where isolated eruptions seem to periodically occur). Illustration of these examples will be described from a non-technical signal detection framework.

From my medical layman's point of view, it seems that medical diagnosis has benefited from a number of technical areas outside medicine, including electronics, basic science areas of investigation (e.g., physiology, biochemistry, physics, etc.), computers, and biomedical statistics. As an example of some of the problems of medical diagnosis, suppose you are told that, on the basis of a medical test you have recently taken, you may have a potentially severe disease known as *Morbus universalis*. One of your first reactions may be to wonder how accurate the test is that provides this diagnosis. After investigating, you find that the test identifies 90 percent of those who have the disease as having it. Does this mean you have it (with a 90-percent probability)? Also relevant is the question of whether or not any miss-identifications are made using this test (i.e., false alarms or false positives). Suppose this test is known to have a false positive rate of 10 percent. This complicates matters. Do you have the disease or not? In addition to considering the 90 percent probability of detecting the disease (if you have it) and the 10 percent false positive rate, there is another factor that must be considered. Suppose you find out that there is another test for the same disease, but it identifies everyone taking it as having the disease whether they have it or not. This certainly ensures that everyone with the disease will be

considered to have it—no one with the disease will be missed. Unless, however, we are dealing with a pandemic of major significance, the false positive rate is likely to be high. This circumstance, however, introduces this other factor to be noted—namely, the prevalence (or base rate) of the disease in the population of similar individuals being tested. Let us say that previous data indicate that for individuals similar to you, the prevalence of Morbus universalis is such that it occurs in 5 people in a thousand. By mentioning these three considerations, the 90 percent rate of correctly detecting that you have the disease (if you have it), the 10 percent false positive rate, and the prevalence of the disease (0.005), it becomes obvious that one's perceptual limitations are being tested. Nevertheless, the observation that you have tested positive for it is likely to be disturbing, and it appears, superficially, that you are likely to have it.

In order to more clearly consider what is happening, let me introduce some standard terms used to describe the considerations just mentioned. When one detects correctly a disease that is present, the detection is called a true positive (TP). If the detection of disease is incorrect and the individual does not have the disease, it is called a false positive (FP). If the disease is not detected, when it is present, it is called a false negative (FN). Finally, we have the circumstance of a determination of non-disease when disease is not present, known as a true negative (TN). The analysis that follows is based on fundamental ideas developed in signal detection theory that were originally applied to the detection of signals in radar (with different, but equivalent, names for the conditions of TP, FP, FN, and TN) and in Bayesian statistical analysis. Signal detection theory has since been applied to sensory and memory phenomena in psychology and, also, to problems of medical diagnosis (Green & Swets, 1966; Swets, 1996).

Now, let us turn our attention to the patient who may or may not have the (fictitious) disease Morbus universalis with consideration of the information just given. I have included some hypothetical possibilities based on a similar population of 100,000 in **Table 9.1**. This is a typical 2 X 2 contingency table that conveniently illustrates each of several given data values along with calculated values from those initially given.

DISEASE MORBUS UNIVERSALIS				
		Disease Present		
		Yes	No	
Diagnostic Test Results	Yes	TP 450	FP 9,950	10,400
	No	FN 50	TN 89,550	89,600
		500	99,500	100,000

[[Table 9.1](#)] *Contingency Table Example*. The tabulated numerical values are based on a population of 100,000, a prevalence of 0.005, a true positive rate of 0.90, and a false positive rate of 0.10.

Table 9.1 illustrates the components contributing to the prediction of the probability one has a disease, based on a diagnostic test having a true positive rate of 0.90, a false positive rate of 0.10, and a disease prevalence of 0.005. Calculations are based on a hypothetical sample of 100,000 with a theoretical true incidence of $100000 \times 0.005 = 500$ with the disease. Of those, $0.90 \times 500 = 450$ are true positives in the sample. The bulk of those with a positive test result are, however, false positives and are calculated as $0.10 \times (100000 - 500) = 9950$. The proportion of people who have Morbus universalis is, therefore, calculated as $450 / (450 + 9950) = 0.0433$ (or 4.33 percent). If the prevalence were 0.001, the resulting percentage would be 0.893 percent. As can be seen the prevalence (or base rate) makes a difference.

I should add, however, that different fields concerned with the type of analysis illustrated in **Table 9.1** use different terms other than TP, FP, FN, and TN (which were used to fit within the resulting table). In signal detection theory TP = Hit Rate, FP = False Alarm Rate, FN = Miss Rate, TN = Correct Rejection Rate, and Prevalence = Base Rate. In medicine, TP = Sensitivity, $1 - FP$ = Specificity, and Prevalence = Prevalence. There are other measures used, as described by Green & Swets (1966) and Swets (1996), that involve what are called receiver (or relative) operating characteristic (ROC) curves,

which are used to provide more extensive information.

Considering TP, FP, FN, TN, and Prev (abbreviation for Prevalence) to be proportions with each ranging numerically within the closed interval [0,1], the predicted probability of the disease being present, or positive predictive value (PPV), is given by the special case Bayesian equation:

$$PPV = TP \times Prev / (TP \times Prev + FP \times (1 - Prev)).$$

By entering the proportions given in the original analysis into the equation for PPV, one will get the same result as originally obtained. The use of a hypothetical population of 100,000 and consequent calculations simply makes the analysis—summarized in the equation for PPV—more understandable. The intuitive (or apparent) discrepancy between the calculated probability of having the disease and the initial impression one may have illustrates the cognitive perceptual limitation one experiences in evaluating a situation involving several variables contributing jointly to a specific conclusion. Parenthetically, there is a similar equation that provides a negative predictive value (NPV) indicating the probability that one does not have a specific disease (if the diagnostic test result is negative). For the data given in **Table 9.1**, the value of NPV = 0.9994 (or 99.94 percent). This result is, also, not intuitively obvious.

What does it mean when someone states that a test has an accuracy of 90 percent? In the popular press this value may represent the percentage of instances in which a disease (or circumstance) is correctly detected when actually present. This is the sensitivity (or hit rate or TP) of the phenomenon being detected. If presented alone, this value may be represented as the “accuracy” of the test without considering either the false positive (false alarm) rate or the prevalence (base rate). By changing to a more lenient criterion (or another test), thereby obtaining a separate probable indication of the disease (or circumstance), the sensitivity (hit rate or TP) increases, as does the false positive (false alarm) rate. As has already been mentioned, if one considers a variation in prevalence, there is also a corresponding change in the positive predictive value. Ignoring the prevalence is known as base rate neglect. Thus, a statement of accuracy as a single percentage measure is not very informative.

The concerns of true positives, false positives, and prevalence apply also to other events. For example, polygraph testing is subject to the same considerations. Suppose, for example, that a polygraph examination procedure that results in a positive indication of deceit is known to have a true

positive (TP) rate 0.85, a false positive (FP) rate of 0.05, and the population from which the examinee is representative has a deceitful prevalence (Prev) of 0.01. Introducing these proportions into the Bayesian equation gives a PPV of 0.147 or 14.7 percent that the examinee is being deceitful. This is far from what would probably be the popularly reported value of 85 percent (based on the true positive rate alone), which gives a highly inflated impression of accuracy. In this case I have used a prevalence (Prev) = 0.01. If Prev = 0.001, this changes PPV to 0.0167 (1.67 percent). It can be seen that knowing the prevalence accurately is essential to knowing the positive predictive value (PPV), although it is not the only value needing quantifiable specification. TP, FP, and Prev each contribute to the final probability of an event. Difficulty in establishing the values of these components can make conclusions controversial. In the absence of a clear and conclusive value for Prev, different people (possibly varying in the degree to which they suspect a conspiratorial basis for an examinee's behavior) may subjectively assign very different values to be used in the calculation of PPV. One prone to the acceptance of conspiracy theories may accept a greater amount of apophrenia than someone else. This problem is reduced in those cases of medical diagnosis for which epidemiological studies provide (in many cases) an externally established value for the numerical sizes of Prev, TP (sensitivity), and FP (1 – specificity). Without knowing these values, the empirical difficulties clearly limit our perceptual boundaries in interpreting reality.

As we move into an even more controversial area of consideration, let me mention some observations regarding gun violence, particularly those involving mass murder. As is generally known, there has been some political discussion about this topic with at least two different positions advanced as solutions. One position is that there need to be more restrictions placed on the access to guns (particularly assault rifles). The other, favored by the National Rifle Association (NRA), among others, maintains that improvements need to be made in identifying those who may be predisposed to violent behavior with guns, for example, “mentally ill” individuals and people with felony records. Felony criminal record may be insufficient to exclude mass murder candidates. This is indicated in the following **Table 9.2** listing of 12 incidents involving more than 10 murdered victims per incident from Columbine (in 1999) to Stoneman Douglass High School (in 2018):

Mass Killer(s)	Killing Location	Year	Criminal History
Nikolas Cruz	Stoneman Douglas High School	2018	No
Devin Patrick Kelley	Texas First Baptist Church	2017	No
Stephen Craig Paddock	Las Vegas Strip	2017	No
Omar Mateen	Orlando nightclub	2016	No
Syed Rizwan Farook	San Bernardino	2015	No
Aaron Alexis	Washington Navy Yard	2013	No
Adam Lanza	Sandy Hook Elementary	2012	No
James Holmes	Aurora theater	2012	No
Nidal Malik Hasan	Fort Hood	2009	No
Jiverly Wong	Binghamton	2009	Yes (misdemeanor)
Seung-Hui Cho	Virginia Tech	2007	No (?)
Eric Harris and Dylan Klebold	Columbine	1999	"No" (2 guns straw purchased)

[[Table 9.2](#)] *Mass Murder Events Involving More Than 10 Fatality Victims Per Incident*

The United States Speaker of the House of Representatives Paul Ryan is satisfied with the status quo (after the Stoneman Douglas High School shooting), as indicated by his statement (usatoday.com, 27 Feb. 2018), "We shouldn't be banning guns for law-abiding citizens, we should be focusing on making sure that citizens who shouldn't have guns in the first place don't get those guns." Note that, technically (as far as I know from published news reports), Nikolas Cruz was a law-abiding (non-felon though, admittedly, not perfect) citizen prior to 14 February 2018. Without a criminal conviction record, he was able to legally obtain the guns he acquired. Speaker Ryan appears to advocate a continuation of policies enabling possession of really dangerous firearms. An assault weapons ban in place might have prevented this tragedy. Eleven of the twelve mass shootings involving more than ten victims (per massacre) killed by guns since the Columbine High School (in 1999) event until the Stoneman Douglas High School event (in 2018) were done by "law abiding" individuals who obtained guns legally.

The approaches to this very complex question have taken curious turns. As a health issue, the Centers for Disease Control and Prevention (CDC) has stopped research into gun violence as a result of the Dickey Amendment (passed by Congress in 1996), reportedly in response to lobby efforts by the NRA. One might expect that members of Congress who receive large

amounts of money from the NRA would, because of the obvious conflict of interest, recuse themselves from votes on matters representing major isolated concerns of the NRA. My concern regarding this may be inappropriate because the political system of the United States seems to be the best that money can buy.

An alternative to solving this admittedly complex social problem is to identify, as well as possible, those who should not have guns. "Mentally ill" individuals are frequently mentioned by the popular press as examples of those who require exclusion from having guns. Let me say, initially, that I am not persuaded that mentally ill people are more likely to engage in gun violence. The data I have seen seem to suggest otherwise, but are incomplete; remember, Congress has actively discouraged attempts to remove ignorance in this matter.

Whichever is the case, let us suppose we have a test called the Mass Murder Predictor Test (MMPT) that can be used (prior to a gun purchase) to predict whether or not an individual is going to commit mass murder. However constituted, the MMPT has a true positive (TP, or sensitivity) rate of 0.99 and a false positive (FP, or $1 - \text{specificity}$) rate of 0.01. The remaining question is to determine the prevalence. If we give the test to a group of institutionalized psychopathic felons, the prevalence may be rather high. If, however, those tested are similar to most of those in Table 9. 2 (or the general population), the prevalence is probably much lower, let us say $\text{Prev} = 0.001$. If a person is tested with the MMPT (with a $\text{TP} = 0.99$ and a $\text{FP} = 0.01$), and comes from a population with a $\text{Prev} = 0.001$, then the positive predictive probability (PPV) $= 0.09$. This means that a person who tested positive with the MMPT has a 9 percent chance of being a mass murderer (and a 91 percent chance of being falsely identified as a mass murderer). I think this suggests that it will be difficult to identify (to anyone's satisfaction) which persons should be prohibited from obtaining guns.

With these examples of detection of disease, deception, and mass murder, it appears that there are obvious perceptual boundaries limiting our ability to evaluate event probabilities that depend on base rates and their influence.

Veridicality

Veridicality: The degree to which our perception accurately represents reality.

When an event (rare or otherwise) happens, there is frequently an attempt to explain its occurrence by making reference to some more general principle (or

law) under which the event may be subsumed as a special case. This kind of explanation, whether a true explanation or pseudo-explanation, seems to be a consequence of modern (and ancient) theorizing. In the remote past (i.e., thousands of years ago) it may have sufficed to account for the occurrence of a phenomenon, particularly a rare event, by indicating that it was a result of the will of the god(s). This kind of argument has prevailed for many people down to the present time, although the proportion of events so accounted for may have diminished. Some refer to this kind of diminished argument as the "God of the gaps" view, which has been used by both "believers" and "unbelievers." I enclose the previous two terms in quotation marks because they have no meaning unless the "God" is explicitly defined. The basic idea of explanation seems, nevertheless, to apply in those cases in which a (e.g., rare) phenomenon occurs for which there is no satisfactory scientific explanation.

Over the years the "God of the gaps" viewpoint seems to have been reduced in size as a result, apparently, of increased scientific knowledge. Until such time as there is complete knowledge of the Universe and its happenings, this viewpoint will probably continue to be used. Interestingly, a Google search of the phrase "nothing left to be discovered" indicates that its reported use may have been apocryphal and attributed, perhaps in error, to a number of 19th century physicists. This was, notably, before relativity and quantum physics became major topics, and subsequent developments in cosmology increased the known size of the Universe (as indicated in Chapter 6).

In those cases, such as the regular appearance of the Sun and Moon in a predictable manner, the occurrence of temporary illness, thunderstorms (with accompanying lightning), and other "naturally occurring phenomena," there have been explanations provided to account for the manifest progression of events within each type of phenomenon. Early explanations may have dealt with these phenomena in terms of control exercised by the god(s), while later views may have used scientific principles as explanatory accounts (with some being correct and others not correct). As I have indicated, an explanation is a procedure by which the occurrence of a phenomenon is accounted for by indicating that it is a special case of the will of the god(s) or of a scientific principle or law. This does not establish the truth (or veridicality) of the explanation. The Ptolemaic (Earth-centered) model of the solar system provided explanations of planetary movements. It was replaced by the Copernican (Sun-centered) system that improved and simplified the explanations required at the time. Scientific explanation is continually evolving in order to account more accurately and simply (if possible) for phenomena being explained. In science it is recognized that the theoretical

formulation adopted may or may not be correct. It is used as a way of summarizing observed data and providing a basis for predictions about what to expect in future data.

In this book I have indicated that a fundamental evolution has occurred in our perceptual boundaries. These boundaries have been modified dramatically in our collective cosmological worldviews over the past several thousand years. There has been a corresponding increase in our cognitive knowledge. This evolution has been possible because of the accumulation of transmitted and preserved knowledge permitting subsequent generations of people to know both new things and, also, cumulative recorded knowledge from the past. Non-humans do not, generally, accumulate knowledge over generations other than by the process of Darwinian changes that may benefit them (or, at least, not be fatally deleterious) in an evolutionary sense. The accumulation of increasing recorded amounts of knowledge by humans reminds one of Moore's law (the increase of the number of transistors on integrated circuit chips over time). Through comparisons between inter-subjective (between individuals) observations and, also, noting whether or not predictions are accurately borne out for future events, we can establish more clearly the veridical nature of our interpretations and perceptions of the immediate and cosmological environments. This is generally accomplished through the active use of the scientific method, which has increasingly been utilized in recent centuries. As I have noted, the development of scientific instrumentation has greatly helped. Although other senses contribute to our perception of reality, I have selectively emphasized vision and audition because these two are senses most people believe they have direct knowledge about, correctly or incorrectly.

Over the past several thousand years our collective and individual perceptions of reality have changed as a result of technological developments. It is possible to observe internal contents of the body in non-invasive ways (thus leaving the individual's body intact and functional). We, also, are able to see objects at vast distances from us, e.g., far beyond the Andromeda galaxy (which was potentially visible in the absence of light pollution thousands of years ago but was not interpretable). Almost instantaneous communication is possible throughout an approximately spherical (not flat) Earth between individuals, and inanimate (although neither von Neumann nor Bracewell autonomous) probes have been sent to far reaches of the Solar System and (at least for five probes) beyond. On Earth it is likely that the agnosias, delusions, and hallucinations of today were prevalent thousands of years ago as well, although different interpretations may have been applied then (e.g., demon possession, etc.).

Many of our perceptions of environmental reality have likely become more veridical, although not all. I have included, particularly in Chapters 5 through 7, numerical instances indicating a perceptual chasm between our existing interpretations of the probabilities of everyday occurrences and their actual estimated probabilities. The ESP experiment utilized a simpler binary choice that enables one to make precise probabilistic statements regarding the likelihood of particular results. It was selected as an unambiguous task for that reason; the mathematical analysis is simple and straightforward. For the more complex situations (some might say quirky) in which one considers events retrospectively, identifying probabilities is much more difficult. What, for example, is the probability of the Earth being positioned exactly where it was some 65 million years ago with the consequence that a similarly fortuitous asteroid trajectory resulted in a collision that killed the dinosaurs (and a lot more)? Nevertheless, by tracing a sequence of improbable events that have led to a particular current event, it is possible to indicate in a very approximate way a rough probability of occurrence for some events.

Through the use of inter-subjective agreement and objective recording of phenomena and events by electronic devices, it is possible to theoretically approach a more veridical view of reality. This would be confirmable through the use of correlational statistics applied to quantified measures of retrospectively observed collections of events. In those circumstances in which one is able to experimentally investigate relationships, it is likely that causal factors may be identified and separated from confounding variables (those stimuli that vary in an uncontrolled way, knowingly or unknowingly, with stimuli of immediate interest) that are likely present in the absence of experimental control of environmental circumstances. This was shown to be a particularly severe problem in the description of the ESP literature in Chapter 5. Normal, abnormal, pathological, and extrasensory perceptions may or may not be veridical. In this book I have indicated some of the perceptual problems which are and which are not.

Summary

Some of our perceptions become anomalous because of perceptual biases used to interpret sensory inputs. As such, they do not provide us with a veridical (accurate) perception of our environment. Apophenia is the frequently automatic attempt to make cognitive sense out of clusters of stimulus events that may be randomly present and are actually unrelated except for temporal proximity. A special case of this is called pareidolia, which is visually interpreting coincidental random collections of visual

stimuli as faces. This automatic cognitive belief, made from clusters of stimuli (visual and non-visual), has been called “patternicity” by Michael Shermer (Shermer, 2008). The tendency to do this is contrasted with veridicality, the view of things and events in an accurate manner.

Generalized beliefs, based on these collections of perceptions, may develop into false belief systems, conspiracy theories, gambler’s fallacies, or other systemized views of reality. Our consequent perceptions are a likely combination of both patternicity (which has its merits) and veridicality. Scientific advances are made when probable veridicality is increased. This is made possible through rigorous experimentation, observation, and replication, when possible, of research findings. In some cases non-veridical beliefs (on the basis of patternicity) may provide hypotheses to be experimentally investigated. Other circumstances may require prudent suspension of belief if the apparent results are not subject to experimental or careful observation.

Cognitive limitations are suggested by inefficient and inaccurate interpretation of compound sets of information, as is illustrated by medical diagnosis from screening tests, lie detector (polygraph) interpretations, and suggested solutions to concerns about gun violence.

Veridicality (or accurate perception of reality) has been an increasing concern of philosophers and scientists (among others). Answers to questions of veridicality seem to be getting more accurate as a consequence of electronic (and other) objective methods of identifying reality. With these more accurate answers, some perceptual boundaries are apparently reduced in their limiting effect while others emerge.

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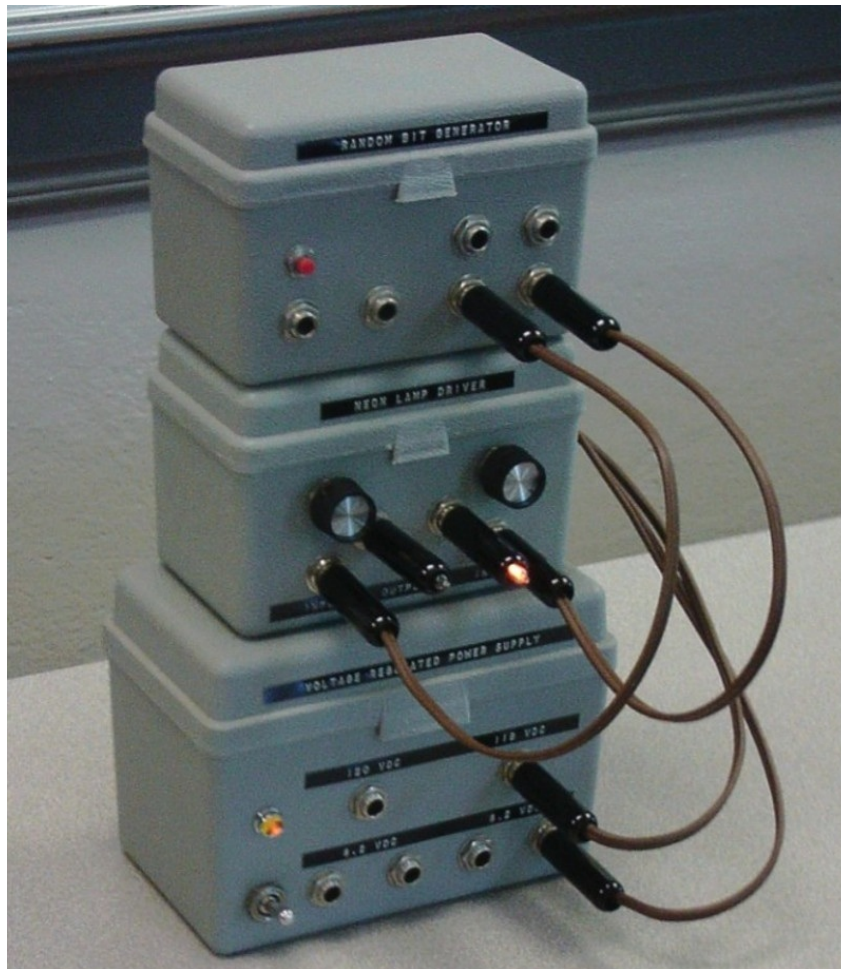
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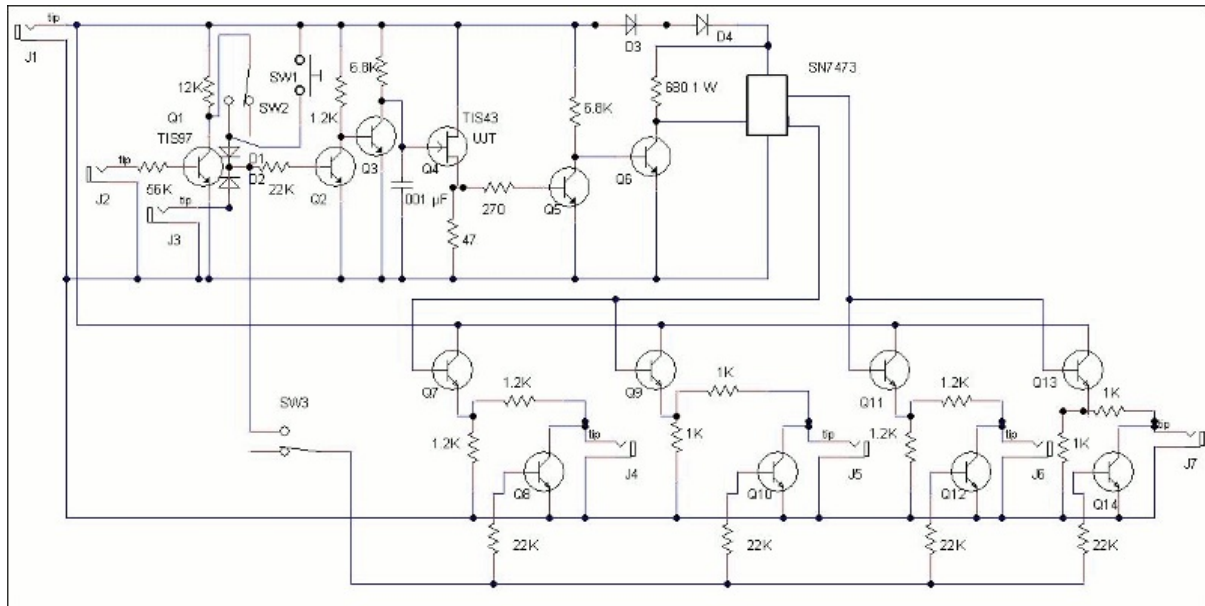
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Appendix A – ESP Experiment Apparatus



[[Figure A1](#)] *ESP Experiment Apparatus*. The three modules (from top to bottom) are the Random Bit Generator, Neon Lamp Driver, and Power Supply for the top two units. The apparatus is pictured in a classroom that was used for many of the 183 experimental sessions.



[Figure A2] *Circuit diagram of the Random Bit Generator. Drawn with TinyCAD.*

Random Bit Generator Circuit Diagram Components:

- J1-J7: Open circuit phone jack
- Q1: TIS97 NPN transistor
- Q4: TIS43 unijunction transistor (not FET)
- Q2&3: 2N3704 NPN transistor
- Q5-Q14: 2N3704 NPN transistor
- D1-D4: 1N4001 silicon diode
- SN7473: Dual JK flip-flop IC
- SW1: Momentary NO push button switch
- SW2&3: SPST toggle switch
- Resistors: Values in Ohms except for those listed with a K (=1000). All are ½-Watt except as noted.

Random Bit Generator Circuit Description:

Power for the Random Bit Generator (RBG) is introduced at jack J1. Jacks J2 and J3 are included for external control and are not functional in the current experiment. Jacks J4-J7 provide outputs for the neon lamp driver with J4 & J5 giving Q and J6 & J7 giving not-Q outputs. The 6.8K resistor in the collector lead of Q3 along with the 0.001 μ F capacitor connecting the base of Q4 with ground determine the frequency of the UJT oscillator (the use of an FET symbol for Q4 resulted from a lack of a correct UJT symbol in the drawing). Diodes D3 and D4 (in series) were included to drop the power supply voltage (6.2 VDC) to a value appropriate for the SN7473 integrated circuit (at the time this was designed, I did not have access to CMOS dual JK flip-flops

such as the CD4027). SW1 was used to activate the toggled alternation between Q and not-Q. SW3, when closed, turned the lamps off while SW1 was pressed. One half of the dual JK flip-flop was used with the output of Q6 driving the clock input. Although there are four RBG outputs, only two are used to drive the neon lamp drivers (e.g., J4 and J6) for the complementary outputs. The completed unit, mounted in a Sterling Plastics File Box is shown as the top unit in **Figure A1**.

Neon Lamp Driver Circuit Description:

For each NE-2H neon lamp a current of 1 mA through a series resistor (47K) to the 118-VDC supply voltage in a conventional common emitter high-voltage (2N5551) transistor circuit was alternately switched on or off at the Random Bit Generator (RBG) output frequency of 46.9 kHz. When one lamp was on, the other was off. A 50K linear taper potentiometer across the input of each transistor driver was connected from the wiper through a 27K resistor to the base of the transistor permitting experimental control of the degree to which the transistor would turn on. The completed unit, mounted in a Sterling Plastics File Box, is shown as the middle unit in **Figure A1**.

Voltage Regulated Power Supply Description:

A Thordason (26R32) power transformer, with a 100K resistor in series with a neon lamp status indicator across its input, provided dual secondary voltages of 117 VAC and 6.3 VAC, which were each connected to separate 200-Volt full-wave diode bridge rectifiers whose output was filtered by a conventional Pi-section filter in the 118-Volt circuit and an L-section filter in the 6.2-Volt circuit. Voltage regulation was provided for both by Zener diodes (one diode for 6.2 V and two diodes in series for 118 V). The regulated outputs were 118 VDC at 8.5 mA and 6.2 VDC at 120 mA. A separate 120 VDC output at 8.5 mA was available but not used in the experiment. The completed unit, mounted in a larger Sterling Plastics File Box is shown as the bottom unit in **Figure A1**.

Note:

The Neon Lamp Driver and Voltage Regulated Power Supply circuits are both modifications of widely available circuits in books (and now online). I have simply altered them as needed (and indicated above in the circuit descriptions). All three units were designed and constructed to function reliably and without failure which, over a period of 38 years, they have.

Appendix B – Auditory Visual Scanner

The circuit is a hybrid combination of analog and digital components. Auditory tones are generated by analog parts of the circuit (UJT relaxation oscillators and an IC audio amplifier), while a 6 step ring counter (based on digital IC's) controlled the scanning of the visual field. The device was designed to be portable except for, in this prototype unit, a requirement for 115 VAC power (indicated by the power cord at the lower left). In contrast to the apparatus shown in Appendix A (used in the ESP experiment), the Auditory Visual Scanner has been only used for instruction.

The following three illustrations (**Figure B1**, **Figure B2**, and **Figure B3**) show the Auditory Visual Scanner used in classroom demonstrations of an example of sensory substitution:



[Figure B1] *Auditory Visual Scanner.* The front of the Auditory Visual Scanner with an Exakta SLR 135-mm lens in place. Lenses of different focal length can be interchangeably installed for different fields of view. The lens aperture may be adjusted to vary sensitivity of the system. Controls in the back of the unit can vary scan rate and sensitivity. See **Figure B3**.



[Figure B2] *Close-up view of the bayonet mount for the Exakta lens (which has been removed). Part of the 5 X 5 matrix of photocells located at the focal plane of the lens can be seen in its recessed position.*



[Figure B3] *Rear view of the Auditory Visual Scanner. Shown are the control for scan rate (top left) , audio level (top right), and phone jack for audio output (bottom right). Audio level (as well as depth of field) is also adjustable via the lens aperture setting.*

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[Table 7.1](#) – Time Required for a Specific Coin Flipping Sequence

[Figure 9.1](#) – A Set of Unrelated Common Symbols Appearing without Apparent Connected Meaning

[Figure 9.2](#) – The Same Components of **Figure 9.1** Rearranged in **Figure 9.2**

[Table 9.1](#) – Contingency Table Example

[Table 9.2](#) – Mass Murder Events Involving More Than 10 Fatality Victims Per Incident

[Figure A1](#) – ESP Experiment Apparatus

[Figure A2](#) – Circuit diagram of the Random Bit Generator

[Figure B1](#) – Auditory Visual Scanner

[Figure B2](#) – Close-up view of the bayonet mount for the Exakta lens (which has been removed)

[Figure B3](#) – Rear view of the Auditory Visual Scanner

Appendix D – About the Author

By formal training I am a mathematical biopsychologist with an undergraduate degree (B.A.) with majors in mathematics and psychology (Millsaps College, 1962), a Master of Science in psychology with additional graduate coursework in mathematics (University of Mississippi, 1965), a Ph.D. in psychology (University of Mississippi, 1967), and postdoctoral research and study in biopsychology (University of Georgia, 1967-1969). Currently, I am a Professor (Emeritus) of Psychology (University of North Alabama) following 40+ years of teaching and psychophysical research in psychology. Paralleling curricular work, I have over the years also studied applied electronics leading to licensure (through a succession of exams given by FCC examiners) as an amateur radio operator (Extra Class license) and commercial radio licensee (Radiotelephone First Class with Ship Radar Endorsement, subsequently converted through FCC license restructuring to my current General Radiotelephone Operator License with Ship Radar Endorsement).

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